California Sixth Grade Earth Science Activities

We are confident you will find the included activities both relevant and engaging. Please direct any questions or comments regarding this set of activities to:

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California Sixth Grade

Earth Science

Plate tectonics accounts for important features of Earth's surface and major geologic events. As a basis for understanding this concept:

a. Students know evidence of plate tectonics is derived from the fit of the continents; the location of earthquakes, volcanoes, and mid-ocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.
   - Drifting Apart
   - Plot your Position
   - Fossil Fill
   - Continental Drift Theory
   - Earth Forces

b. Students know Earth is composed of several layers: a cold, brittle lithosphere; a hot, convecting mantle; and a dense, metallic core.
   - Layers of the Earth

e. Students know major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.
   - Plotting the Evidence
   - Topping off Mount St. Helens
   - Isn't it Interesting: Shaking up the Facts

g. Students know how to determine the epicenter of an earthquake and know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region.
   - Quake Quest

Many phenomena on Earth's surface are affected by the transfer of energy through radiation and convection currents. As a basis for understanding this concept:

a. Students know the sun is the major source of energy for phenomena on Earth's surface; it powers winds, ocean currents, and the water cycle.
   - Tub Temps
   - On Location
   - Heat Bands
   - Heat Transfer

d. Students know convection currents distribute heat in the atmosphere and oceans.
   - When Hot and Cold Meet
   - Colored Ice Cube
   - Tub Temps
   - On Location
   - Heat Bands
   - Heat Transfer

Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for formation. As a basis for understanding this concept:

a. Students know different natural energy and materials resources and classify them as renewable or non-renewable.
   - Natural Resources, Renewable and Nonrenewable
   - Let's Recycle
   - Mini Water Treatment Simulation
   - Measuring Trees
   - Being Resourceful

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept:

f. Read a topographic map and a geologic map for evidence provided on the maps and construct and interpret a simple scale map.
   - Trail Blazers
   - Plod and Plot
   - Scale the Room
   - Rallying Around
   - Handy Maps
   - Mystery Mountain

Drifting Apart

Topic
Continental drift theory

Key Question
How might the land on Earth have once been joined together as one supercontinent?

Introductory Statement
Students will use a jigsaw puzzle format to determine how the continents may have once fit together.

Guiding Documents
National Geography Standards

- *Account for the patterns of features associated with the margins of tectonic plates such as earthquake zones and volcanic activity (e.g., the Ring of Fire around the Pacific Ocean, the San Andreas Fault in coastal California)*
- *Predict the potential outcome of the continued movement of Earth's tectonic plates (e.g., continental drift, earthquakes, volcanic activity)*

NCTM Standard

- *Understand and apply reasoning processes, with special attention to spatial reasoning and reasoning with proportions and graphs*

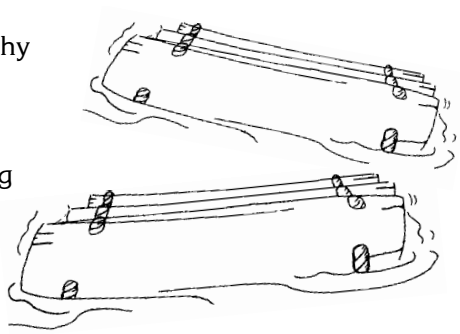
Project 2061 Benchmarks

- *Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.*
- *Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.*
- *Events can be described in terms of being more or less likely, impossible, or certain.*

Social Science
History/geography
world

Math
Spatial reasoning

Science
Earth science
geology



Integrated Processes
Observing
Comparing and contrasting
Inferring

Materials
Scissors
Optional:
scraps of cloth or unbleached muslin, about 30 cm x 43 cm (12" x 17")
transparency of activity sheet
copy paper
glue

Background Information

When Alfred Wegener first proposed the continental drift theory in 1912, it was rejected by the scientific community (see *Continental Drift Theory*). While he had geological evidence that the continents had changed positions, he had no explanation for what caused them to drift. Accumulating evidence and the development of the plate tectonics theory in the 1960's won over many scientists.

Plate tectonics, the theory that the Earth's crust is split into several plates which float on a semi-molten layer of rock in the upper mantle, offers a possible explanation for continental drift as well as for earthquake and volcanic activity.

Both continental drift and plate tectonics, however, are still theories. Scientists today are searching for more evidence, evidence which may support their thinking or send them in a new direction.

During Earth's history, have there been other supercontinents like Pangaea? Evidence suggests that the continents have come together and then drifted apart possibly four or five times; Pangaea, estimated to have occurred some 200 million years ago, is just the latest in this seemingly continuous cycle.

The possible joining of the continents would have happened along the edges of the continental shelves, not the shorelines. The shorelines have changed due to variable water levels and the growth of new formations over millions of years. For this reason, the continental shapes used in this activity are more general than the images we usually see on a world map. Also, India was thought to be separate from Asia millions of years ago.

The actual continent-to-continent fit that may have made up Pangaea is described in *Procedure* and illustrated on the fact sheet. The evidence most strongly

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supports the position of South America adjoining western Africa. The other continental positions do not have as much documentation and, therefore, maps in various sources may differ somewhat.

Management

1. Partners are recommended for this activity.
2. A transparency of the land masses, cut apart, can help illustrate their position in Pangaea.
3. Because the Earth is spherical, it is impossible to give an accurate representation of the continents on a flat surface. To minimize this distortion, the land masses on a globe can be traced onto cloth by students and used to reconstruct Pangaea.

Procedure

1. Ask the *Key Question*.
2. Have students label and cut out the land masses on the activity sheet. Using a world map, have them draw a compass rose on each piece to compare the present orientation with the positions when Pangaea may have existed.
3. Give students a specified amount of time, five to ten minutes, to explore how the supercontinent may have fit together.
4. Announce the directions for placing the land masses in the positions suggested by the continental drift theory. Transparent land mass pieces may be used for visual assistance.

Directions for Pangaea

a. Place the eastern edge of South America against the lower western half of Africa.
b. Move the eastern coast of North America so that it touches the northwestern side of Africa.
c. Set southern Eurasia so that it joins North America and northern Africa. (The exact position varies with the source.)
d. Sandwich Greenland between North America and Eurasia.
e. Position western India against eastern Africa.
f. Place western Australia next to eastern India.
g. Connect eastern Antarctica with southern Australia.
h. Join Antarctica with southern Africa.

5. Have students glue the pieces in place on another sheet of paper (optional).
6. Give students the fact sheet, *Continental Drift Theory*. Review the information on the fact sheet and discuss the questions.

Discussion

1. Do you think Pangaea once existed? Why or why not?
2. In which direction does each of the continents seem to be moving? How might the Earth look several million years from now?
3. Compare maps of the earthquake areas, volcanic belts, and the Earth's plates. What do you notice?

Extensions

1. Study a map of the ocean floors. Trace the mid-ocean ridge and the connecting mountains as they wind continuously through the world. Notice that all the ocean waters are joined.
2. Have students research the life of the explorer and meteorologist, Alfred Wegener. He is buried in Greenland where he died while on an expedition.
3. Further study the geological evidence Wegener used to formulate his continental drift theory by locating maps illustrating matching fossils, mountains, and climate patterns, particularly between Africa and South America.
4. Research the developments in the 1960's which led to the idea of plate tectonics. Pretend you are a reporter for *Scientific American*; write an article explaining the *who, what, when, where,* and *why* of these developments.

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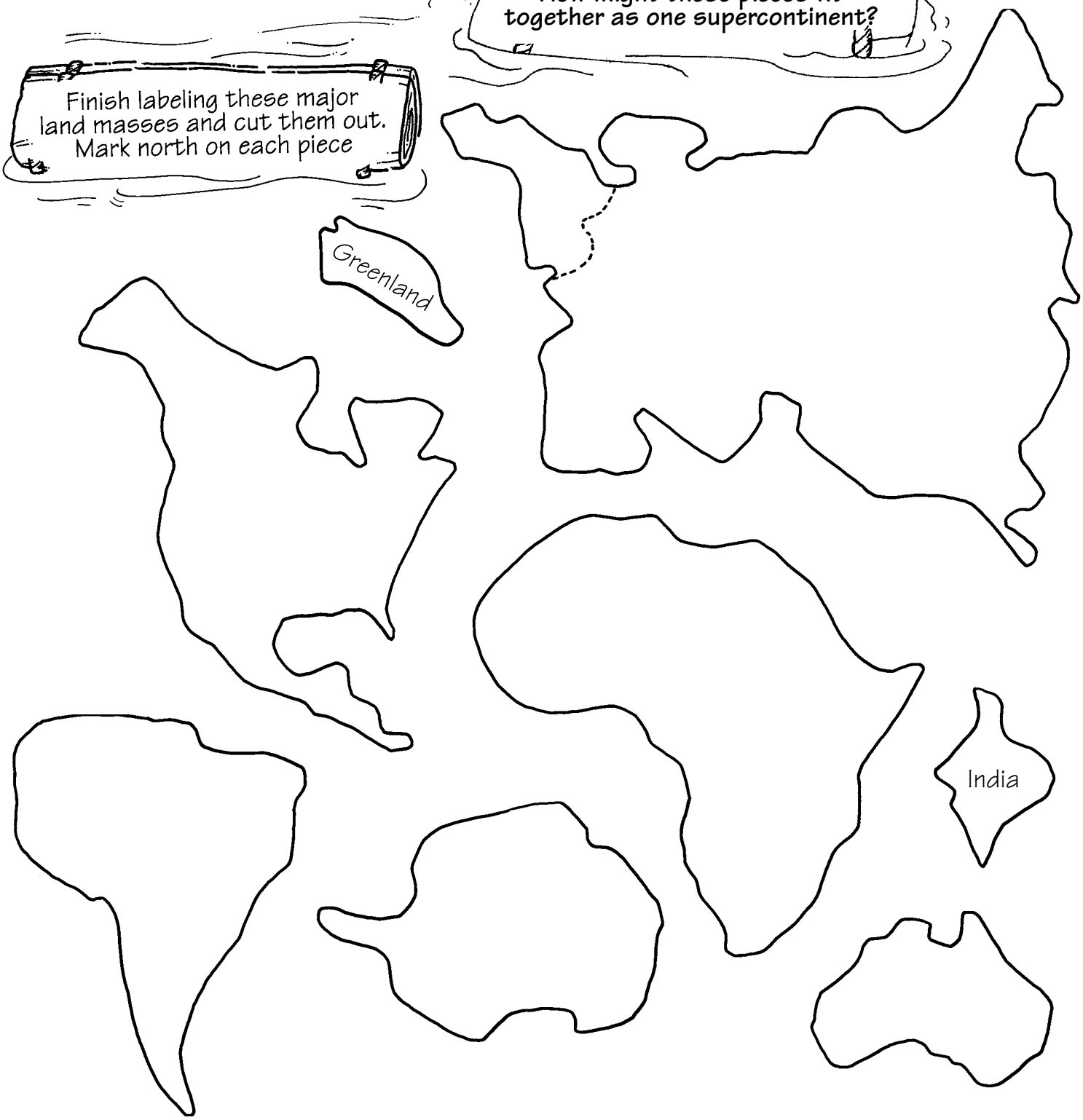
Drifting Apart

How might these pieces fit together as one supercontinent?

Finish labeling these major land masses and cut them out. Mark north on each piece



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PLOT YOUR POSITION

Topic
Longitude and latitude

Key Question
A new country has just been discovered. Where in the world is it?

Focus
Students will plot the boundaries of a fictitious country using the coordinate points of latitude and longitude.

Guiding Documents
National Geography Standards

- *Construct diagrams or charts to display spatial information*
- *Use a map grid to answer the question—What is this location?—as applied to places chosen by the teacher and student*

Project 2061 Benchmarks

- *It takes two numbers to locate a point on a map or any other flat surface. The numbers may be two perpendicular distances from a point, or an angle and a distance from a point.*
- *Find and describe locations on maps with rectangular and polar coordinates.*

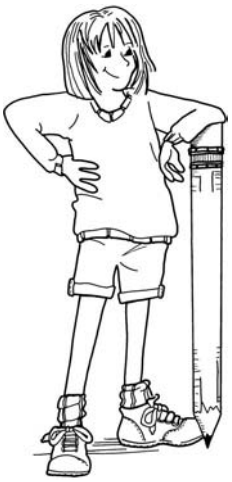
NCTM Standard

- *Understand and apply reasoning processes, with special attention to spatial reasoning and reasoning with proportions and graphs*

Social Science
Geography
world

Math
Coordinate plotting
Spatial sense

Integrated Processes
Predicting
Observing
Making/reading maps
Interpreting data



World map
Transparency of grid, optional

Background Information

The Northern and Southern Hemispheres are divided by the Equator. Lines north of the Equator are northern latitudes. Lines south of the Equator are southern latitudes.

The Eastern and Western Hemispheres are divided by the prime meridian. The 180 degree longitudinal line, which defines much of the international date line, continues this division around the world. Lines east of the prime meridian are eastern longitudes. Lines west of the prime meridian are western longitudes.

For convenience, a flat grid has been provided with equal space between each latitude and each longitude line. In actuality, longitude lines are not equidistant. See *Latitude and Longitude* for further information.

When graphing ordered pairs in mathematics, the first number of the pair is located along the horizontal axis and the second number along the vertical axis, an "across and up" pattern. The opposite is true when plotting latitude and longitude on a map grid. The first number, latitude, is found along the vertical axis and the second, longitude, along the horizontal axis, an "up and across" pattern.

Management

1. This activity may possibly take three time periods–one to review map concepts, another for using the practice grid, and a third to plot the fictitious country.
2. Two levels of difficulty have been provided, *A* being the easier one. Choose the one appropriate for your class.
3. Have students record their predictions on the *Data* sheet before giving out the *Map*. The map grid gives visual clues to the country's location.
4. Some experience with coordinate plotting might be helpful.
5. The finished map should look like the map in *Physically Featured*.

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Procedure

1. Review map concepts (latitude, longitude, Equator, prime meridian, hemispheres, directions, etc.).
2. Have students practice plotting points on either *Practice A* or *Practice B*, if needed.
3. Give students the *Data* sheet first and have them record their predictions.
4. Distribute the *Map*. Instruct students to plot the points independently, reminding them that latitude is found first, followed by longitude. It may be helpful to plot the first few points on an overhead transparency to get them started.
5. Have students number each point as they plot it and connect all points, in order, with a ruler.
6. Upon completion, direct students to use a world map to see exactly where this fictitious country would lie if it existed.
7. For further map reading practice, have students cover the latitude/longitude table. Call out the various numbers they used to label their points (1-13) and have students give the latitude/longtitude readings.
8. Lead a class discussion.

Discussion

1. How does the shape of your country compare to others?
2. In which hemispheres does this fictitious country lie? [Southern, Western]
3. Is it possible to live in more than one hemisphere at a time? Explain. [Yes. We all live in two: Northern or Southern and Eastern or Western.]
4. Which ocean surrounds this country? [Atlantic]
5. What is the nearest existing continent? [South America]
6. What clues in the latitude/longitude table help you establish this country's location in relation to the rest of the world? [directions (N, S, E, W), the distance of the numbers from 0° latitude or longitude]
7. What is another word for 0° latitude? [Equator]…for 0° longitude? [prime meridian]
8. Imagine a fictitious country of your own. What are its latitude and longitude boundaries? In which hemispheres does it lie?

Extensions

1. If you have a large world map with a laminated surface, plot the country directly on it so students can observe the fictitious country's position in relation to the rest of the world.
2. Discuss who might have discovered this country, what kind of people might live there, and what language might be spoken.
3. Make up a name for the country.
4. Find the latitude and longitude for the city or town where you live. What other cities or town lie along the same lines?
5. Do the follow-up activities, *Physically Featured* and *Economically Speaking*.
6. Have students research information about the Tropic of Cancer and the Tropic of Capricorn.

Curriculum Correlation

Language Arts

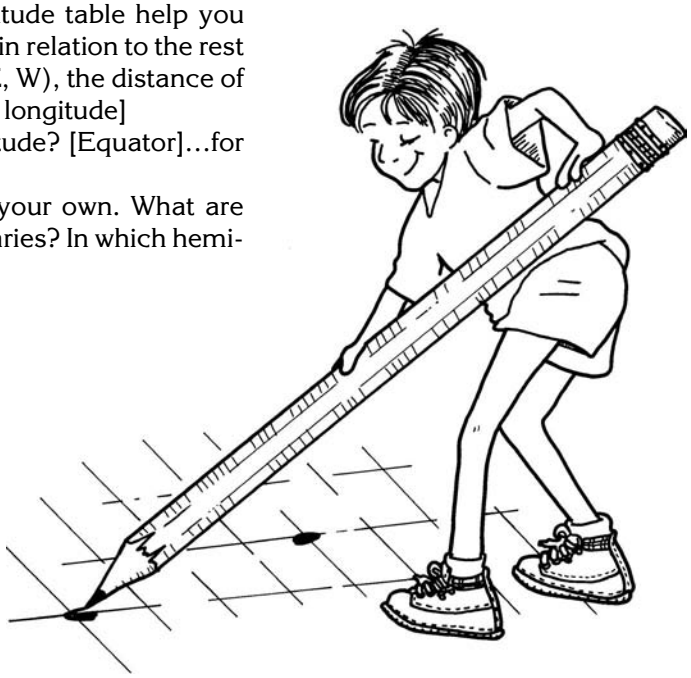
Write a news article, *New Country Discovered by*...!

Math/Technology

Have students construct the country using *Logo*. They will first need to make angle measurements at the coordinate points.

Science

Based on its location, research what the climate might be like in this fictitious country. What seasonal changes might occur and at what times of the year? How would the seasons compare with those in your area?



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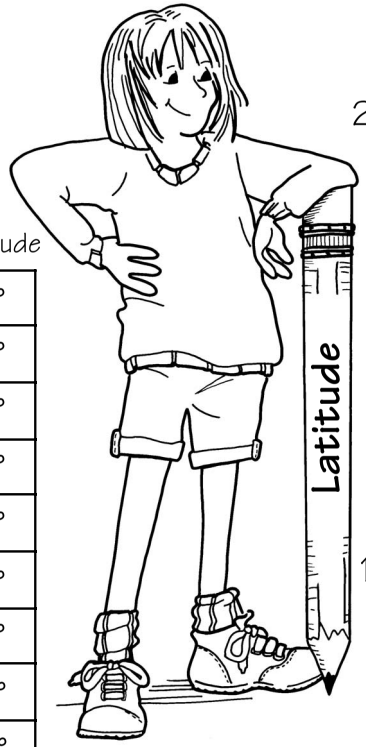
PLOT YOUR POSITION

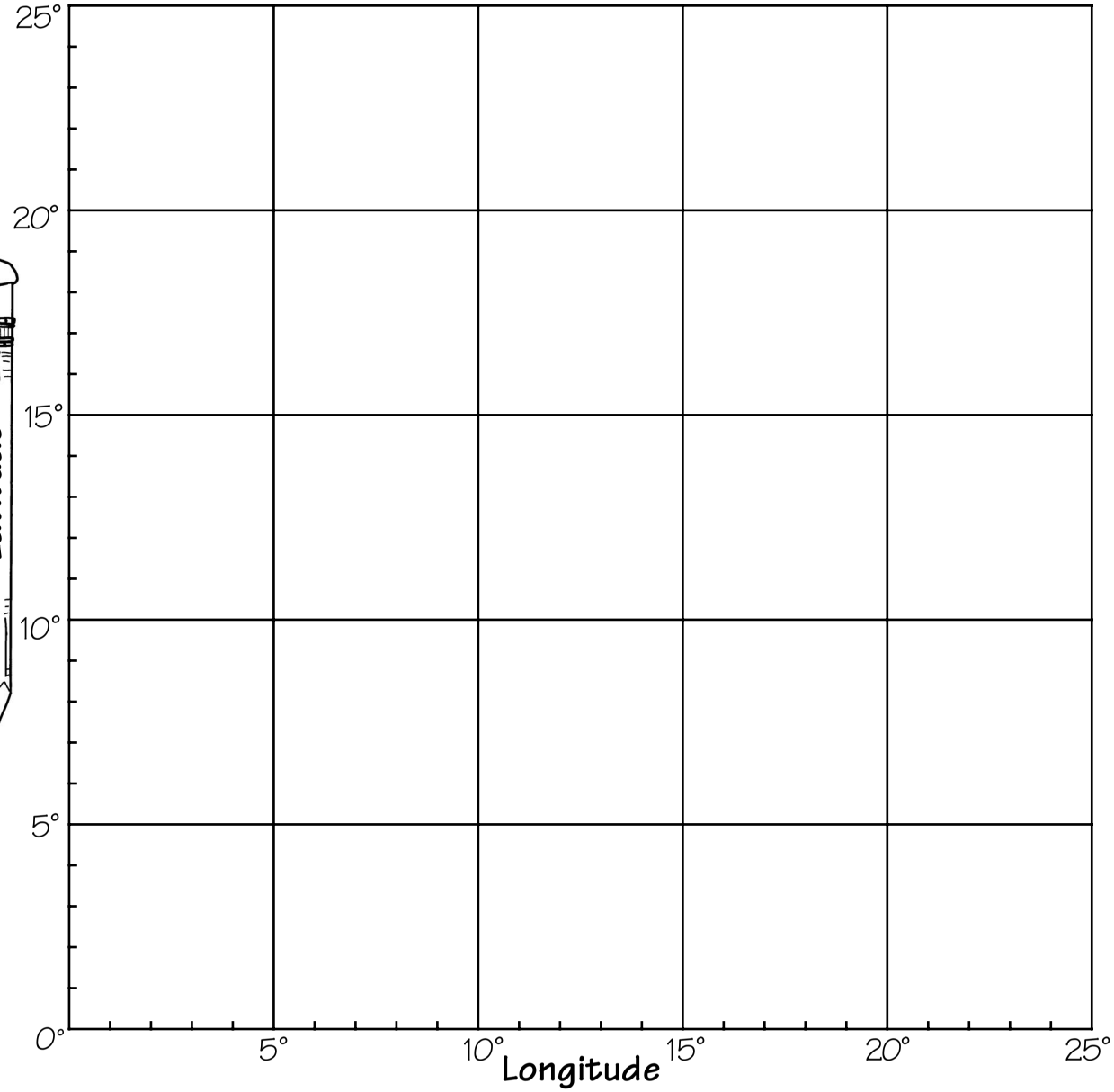
Cartographer

Practice A

Plot and number each point.
Connect it to the previous point with a ruler-drawn line.



	Latitude	Longitude
1.	0°	12°
2.	10°	5°
3.	10°	10°
4.	15°	5°
5.	15°	10°
6.	20°	8°
7.	20°	17°
8.	15°	15°
9.	15°	20°
10.	10°	15°
11.	10°	20°
12.	0°	13°
13.	0°	12°



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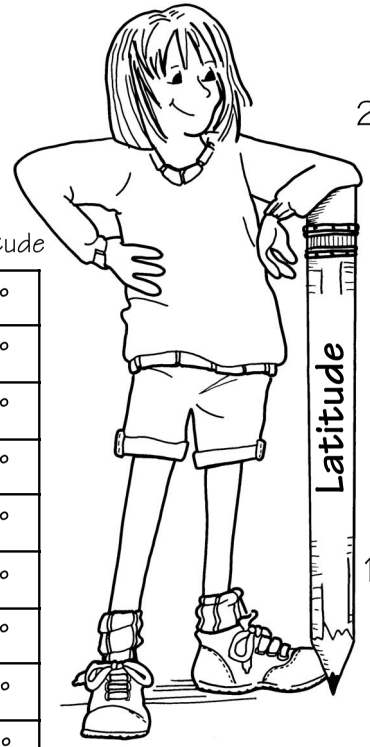
PLOT YOUR POSITION

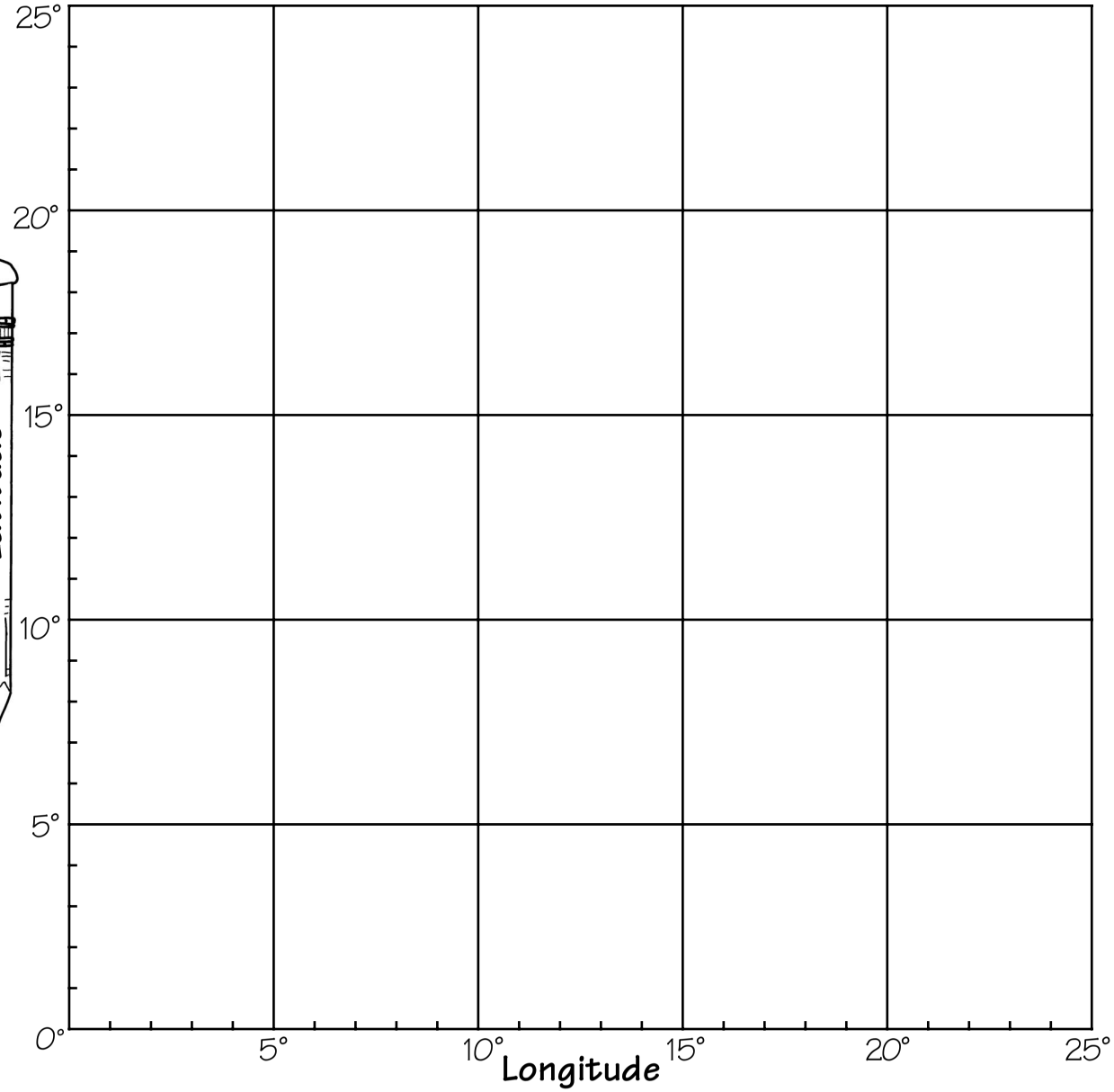
Cartographer

Practice B

Plot and number each point.
Connect it to the previous point with a ruler-drawn line.



	Latitude	Longitude
1.	0°	10°
2.	1°	3°
3.	6°	8°
4.	14°	1°
5.	17°	11°
6.	22°	7°
7.	22°	18°
8.	17°	14°
9.	14°	24°
10.	6°	17°
11.	1°	22°
12.	0°	15°
13.	0°	10°



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PLOT YOUR POSITION

_____
Cartographer

Map A Data

When plotted and connected, the latitude/longitude points below will create a fictitious country somewhere in the world. Where will the country be located?

	Prediction	Actual
Hemispheres:	_____	_____
Ocean:	_____	_____
Nearest continent:	_____	_____

	Latitude	Longitude
1.	10°N	95°W
2.	0°	90°W
3.	5°S	75°W
4.	10°S	80°W
5.	15°S	75°W
6.	20°S	80°W
7.	25°S	85°W
8.	30°S	90°W
9.	30°S	100°W
10.	20°S	100°W
11.	20°S	110°W
12.	10°S	120°W
13.	5°S	115°W
14.	5°N	115°W
15.	0°	105°W
16.	10°N	95°W

_____
Country's Name

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PLOT YOUR POSITION

_____
Cartographer

Map B Data

When plotted and connected, the latitude/longitude points below will create a fictitious country somewhere in the world. Where will the country be located?

	Prediction	Actual
Hemispheres:	_____	_____
Ocean:	_____	_____
Nearest continent:	_____	_____

	Latitude	Longitude
1.	5°N	95°W
2.	4°N	84°W
3.	0°	80°W
4.	4°S	78°W
5.	10°S	82°W
6.	20°S	80°W
7.	22°S	90°W
8.	30°S	98°W
9.	42°S	104°W
10.	38°S	108°W
11.	30°S	106°W
12.	20°S	120°W
13.	14°S	114°W
14.	2°S	114°W
15.	2°N	104°W
16.	5°N	95°W

_____
Country's Name

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PLOT YOUR POSITION

Cartographer

MAP

10°N					
0°					
10°S					
20°S					
30°S					
40°S					
50°S 120°W	110°W	100°W	90°W	80°W	70°W

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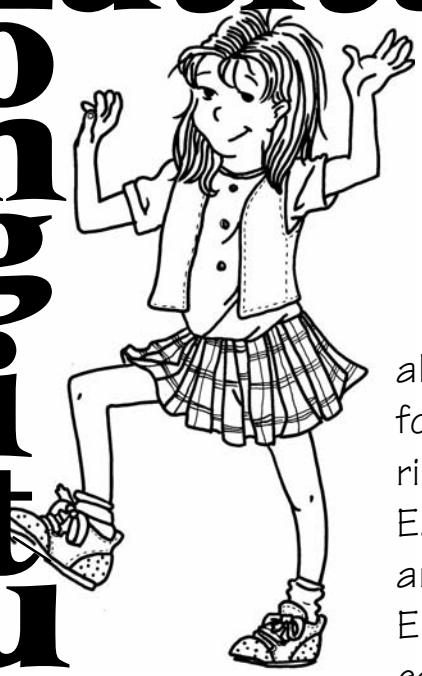
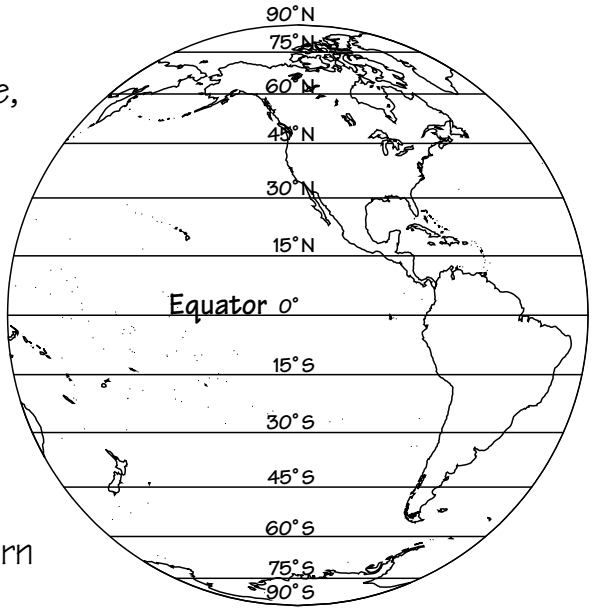
Latitude

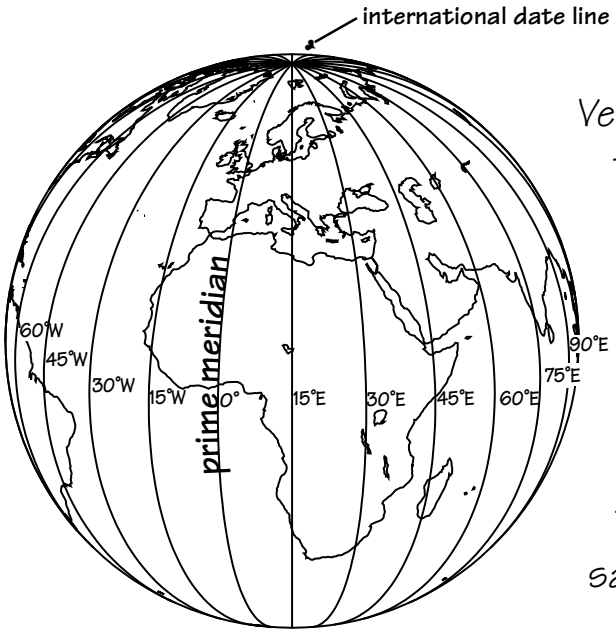
Longitude



People have devised a system of parallels and meridians that form an imaginary grid for locating positions anywhere on Earth.

The lines of latitude, also called parallels, form horizontal rings around the Earth. All latitudes are parallel to the Equator and equidistant from each other. The Equator, 0° latitude, marks the division between the northern latitudes and southern latitudes.





Vertical lines stretching from the North Pole to the South Pole are called lines of longitude or meridians. They are not equidistant; their spacing narrows as they approach the poles.

The prime meridian, 0° longitude, runs through Greenwich, England and divides the eastern from the western longitudes. The international date line, 180°, does the same on the opposite side of the world.

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Fossil Fill

by David Mitchell

Topic
Fossils

Key Question
How can we use fossils to date the relative age of a set of rocks?

Focus
Through three experiences students will learn how paleontologists use the Principle of Superposition to determine the relative ages of fossils.

Guiding Documents
Project 2061 Benchmarks

- *Many thousands of layers of sedimentary rock provide evidence for the long history of the earth and for the long history of changing life forms whose remains are found in the rocks. More recently desposited rock layers are more likely to contain fossils resembling existing species.*
- *Fossils can be compared to one another and to living organisms according to their similarities and differences. Some organisms that lived long ago are similar to existing organisms, but some are quite different.*
- *Thousands of layers of sedimentary rock confirm the long history of the changing surfaces of the earth and the changing life forms whose remains are found in successive layers. The youngest layers are not always found on top, because of folding, breaking, and uplift of layers.*

NRC Standards

- *Fossils provide important evidence of how life and environmental conditions have changed.*
- *Fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time.*
- *People have always had questions about their world. Science is one way of answering questions and explaining the world.*

NCTM Standard

- *Develop an appreciation of geometry as a means of describing the physical world*

Math
Spatial sense
Ordering

Science
Earth science
  paleontology
  relative dating

Integrated Processes
Observing
Comparing and contrasting
Collecting and recording data
Interpreting data
Predicting
Generalizing
Applying
Communicating
Inferring

Materials
For teacher preparation:
  pint-size bottle(s) of rubbing alcohol (see *Management 4)*
  food coloring
  three different forms of pasta (see *Management 3)*
  model horizon (see *Management 5*)

For each student group:
  liter box or liter bottle (see *Management 1*)
  rice in a one-gallon resealable bag (see *Management 2*)
  plastic spoon
  dyed pasta (see *Management 4*)
  prepared cards (see *Management 6*)

Background Information
Paleontology is the study of past life on the surface of the Earth. Paleontologists study organisms of the past to infer what life was like on the planet. The study of fossils and the exploration of what they tell scientists about past climates and the environments of Earth's past is interesting for students of all ages. Teaching about the history of the Earth can be challenging for teachers. This activity addresses the idea of relative dating when placing organisms in imaginary layers of rocks. Scientists use direct evidence from observations of rock layers to help determine the relative age of a layer of rocks. Specific types of environments form specific types of sedimentary rocks. Limestone indicates a marine environment was present during formation and sandstone with ripple marks may indicate a shoreline habitat or a riverbed.

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In the early nineteenth century, scientists studying exposed rock layers in various parts of the Earth concluded that rock layers could be correlated from place to place. The Principle of Superposition states that in an undisturbed horizontal sequence of rocks, the oldest rock layer will be on the bottom, with successively younger layers on top of these. Fossils found in specific layers helped scientists "date" the layers when they examined evidence from other parts of the world. This idea of *relative dating* tells scientists if a rock layer is older or younger than another. Applying the idea of superposition to fossils also helped scientists place past life in a relative sequence. They were also able to establish that some fossils existed only in certain layers. These fossils were referred to as index fossils.

Management

1. You will need to make sure you have a clear container — a liter box or a liter bottle — for each group. The containers will be used to construct rock layers columns. The containers need to be marked with equal-spaced lines. Liter boxes are already calibrated. Some liter bottles have equally-spaced indentations that can serve as markings. If no markings exist, use a permanent marker to indicate increments of equal volume.
2. Each group will need to have enough rice to fill a liter box or liter bottle. The rice represents sedimentary rock.
3. Select three different forms of pasta such as bow tie, wheels, and spirals. The pasta represents fossils.
4. To dye the pasta with food coloring and rubbing alcohol, add approximately half a bottle of food coloring to a 16-oz bottle of rubbing alcohol. Put the pasta into a large mixing bowl and pour the colored alcohol mixture over it. Coat the pasta as evenly as possible and then spread it out on many layers of newspaper to dry overnight. Do this in a well-ventilated area or outdoors. All the pasta forms can be dyed the same color, or different colors can be used to adjust the activity's level of difficulty. If each form of pasta is a different color, the students can quickly see the differences in the "types of fossils." Dying the same form of pasta different colors would allow for more "types of fossils." Additional forms of pasta would also allow for more "types of fossils."
5. After the pasta has dried, prepare a sample horizon to show the students. To do this you will begin by placing a few of one form of pasta in the bottom of the container and adding rice to make the layer. You will alternate the rice and different forms of pasta as you contine to fill the container. Make certain that some of the pasta is against the sides of the container so they can be observed. By observing your container, students should be able to infer the relative age of the three different "fossils" in your column. For example, they should note that only the bow ties are in the bottom layers, the spiral pasta overlaps the bottom and middle layers, and the wheels are found in the middle and upper layers. The students would then infer that the bow ties are oldest, the wheels are youngest, and the spirals are somewhere in age between the oldest and youngest. (Students will determine their own layering to establish the relative age of the "fossils" in their column.)
6. Prepare the two sets of cards for each group.

Part 1

1. Discuss with the students what extinction means. Make sure they understand that when an organism is extinct, it is gone forever. It will not reappear later.
2. Ask the students what they would expect to see if they could dig a deep hole. Lead them in a discussion of layering. In the hole, grass would be first, then a layer of roots and other organic materials followed by a mixture of soil and rock.
3. Ask the students if they have ever taken a trip where mountains have been "cut away" to make room for the road. Did they notice the layers of the rock? (Road cuts have provided paleontologists valuable resources in their study of past life on the planet.)
4. Show the students the sample horizon you prepared. Hand out the pasta, bag of rice, spoon, and clear container to each group and describe how you constructed your horizon.
5. Have the students decide the relative ages of the pasta fossils for their group. Each group should have a unique relative age sequence.
6. Invite the students to exchange models and interpret the relative ages of the fossils in the horizons. Have students identify which layers contained each type of fossil. (Example: Bow ties were only found in layers 0-30 in the liter box.)

Part 2

1. Review again what extinction means. Discuss what they observed in the model horizons they constructed. Tell the students you are distributing some cards that have the names of extinct organisms on them. Inform them that their task is to place the cards in order from the oldest organisms to the youngest organisms.
2. Hand out the student sheets with the names of the extinct organisms. Have the students cut out the cards and ask them to put the cards in order. Give them only the clue that the *Zag Zig* card has the oldest organism on it. Direct them to stack them in a vertical column. (Make certain that the students realize that the column of cards represents a vertical column in the Earth.)
3. Ask the students what clues they used to place the cards in the correct order. [Since *Zig* was in the oldest layer, and it is also found on one other card, that card is next to the layer.]
4. Discuss with the students the Principle of Superposition that states that in an undisturbed horizontal layer, the oldest layer is on the bottom and the youngest layer is on the top.
5. Ask students how they know that *Tin* is older than *Kin*.

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6. Have the students list the organisms from oldest on the bottom to youngest at the top.
   Zag Zig (oldest)
   Zig Bip Zin
   Zin Win
   Win Tin Kin
   Tin Kin
   Kin Kit
   Kit Sit Mit
   Mit Zit (youngest)

Part 3

1. Distribute the student pages of cards with organism pictures. Inform the students that each card represents a vertical rock layer. Have them cut out the cards and order them in the same manner they sequenced the first set, stacking them vertically. Tell them that the card with the asterisk (*) is the oldest layer.
2. Have each group share their column and how they solved the problem.

Discussion

1. What is the Principle of Superposition?
2. What fossils could be used as possible index fossils?
3. Could a gastropod be used as an index fossil? Why or why not?
4. In what types of rocks would you find these fossils? [sedimentary rocks — limestone, sandstone, shale]
5. If you found a Masauro below a layer that contained a trilobite, what could you infer about the layers of rock in this area? [The rock layers have been disturbed as a result of the Earth's movement — an earthquake, erosion, etc.]

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The Principle of Superposition

In an undisturbed horizontal sequence of rocks, the oldest rock layer will be on the bottom, with successively younger layers on top of these.

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FOSSIL FILL

Part 1

Illustrate the sample horizon and indicate the oldest "fossils" and the youngest "fossils."

Part 2

Number the cards in order from oldest(8) to youngest(1) organisms.

ZAG ZIG	MIT ZIT
KIN KIT	KIT SIT MIT
ZIN WIN	TIN KIN
WIN TIN KIN	ZIG BIP ZIN

Part 3

Explain how you determined the relative ages of the organisms.

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ZAG ZIG	MIT ZIT
KIN KIT	KIT SIT MIT

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TIN KIN

ZIG BIP
ZIN

ZIN WIN

WIN TIN
KIN

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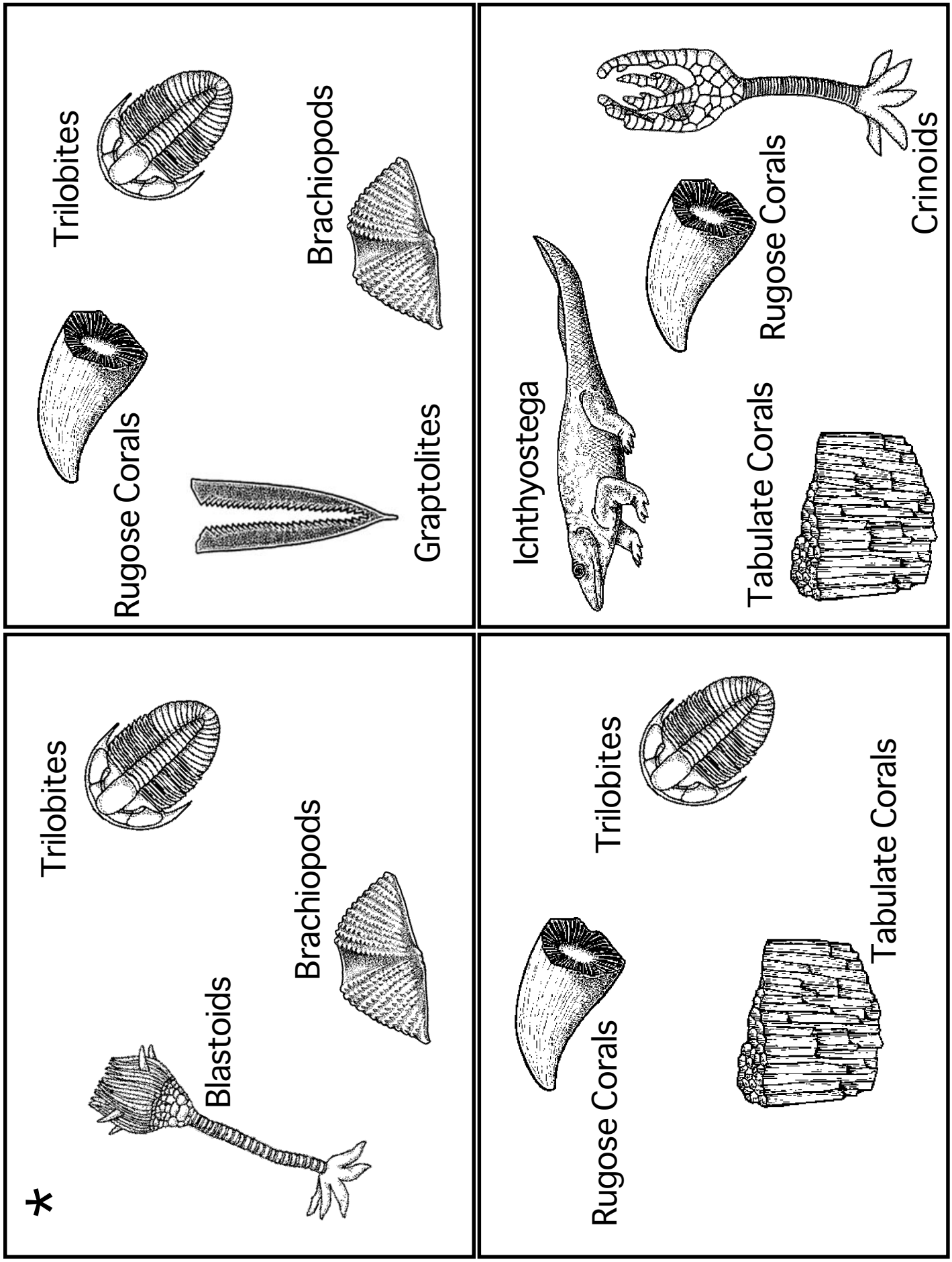

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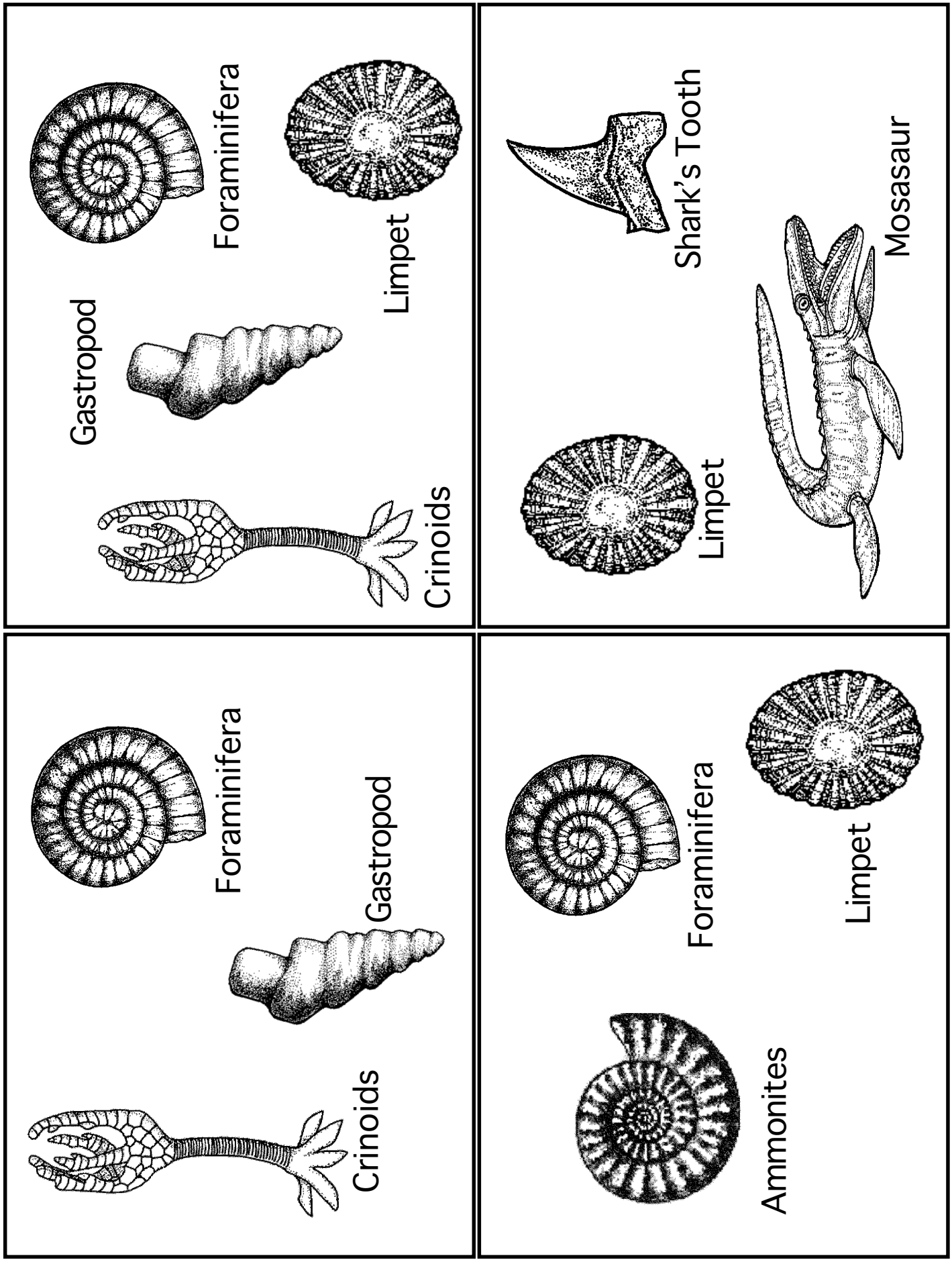

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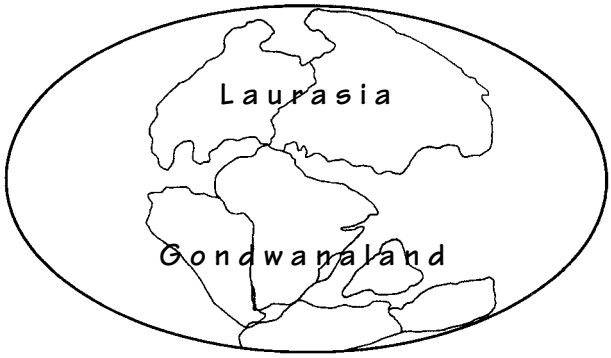
Continental Drift Theory

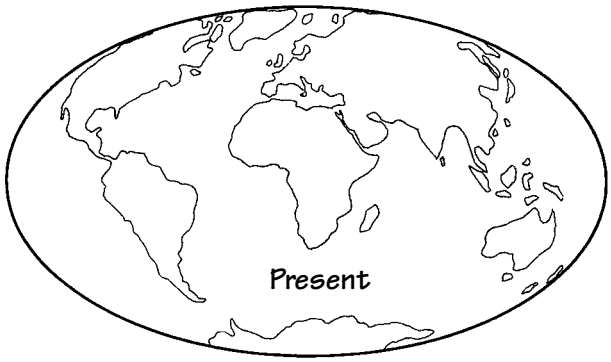
A Pioneer

In 1912 the German meteorologist and explorer, Alfred Wegener (1880-1930), presented the theory that the continents were once joined together in one big land mass and have, over millions of years, slowly drifted apart into their present positions. He named this supercontinent Pangaea (pan jē´ə), a Greek word meaning "all lands".

Over time, he believed that Pangaea split into two subcontinents. Laurasia in the north contained present-day Asia, Europe, and North America. Gondwanaland in the south included South America, Africa, India (then separate from Asia), Australia, and Antarctica. Today there are seven continents.

Wegener based this theory of continental drift on evidence that came from studying rocks, fossils, and the climate of the various continents. The fossils and mountains at the southern tip of Africa match those of Argentina, as do the diamond fields of South Africa and Brazil. Fossils of similar land animals have been found in the rocks of Asia, Europe, and North America. A change in the position of the continents would also explain why plants similar to those in tropical areas once grew in Greenland and Europe while glaciers once covered the Equatorial regions of Africa and Brazil.





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Wegener's *continental drift theory* was fiercely rejected at that time. What did a meteorologist, an outsider, know about geology? Although he had geological evidence to support his theory, he had no explanation for what caused the continents to drift. In the 1960's, new data acquired from mapping the ocean floor, monitoring seismic activity, and investigating the Earth's magnetic fields led to a more encompassing theory, plate tectonics, that explained how continental drift could happen. Since then, scientists have generally come to accept the continental drift theory.

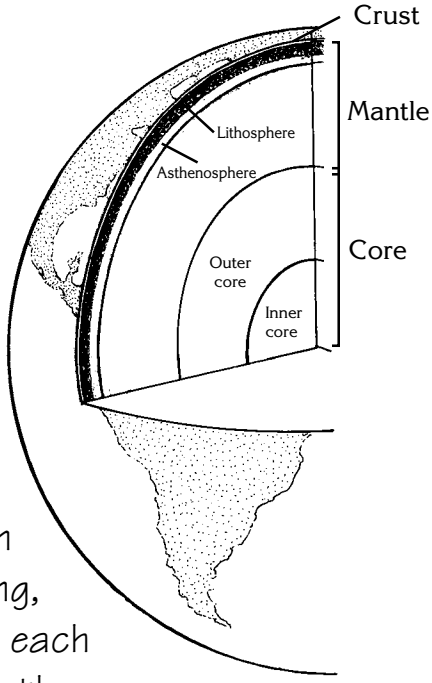
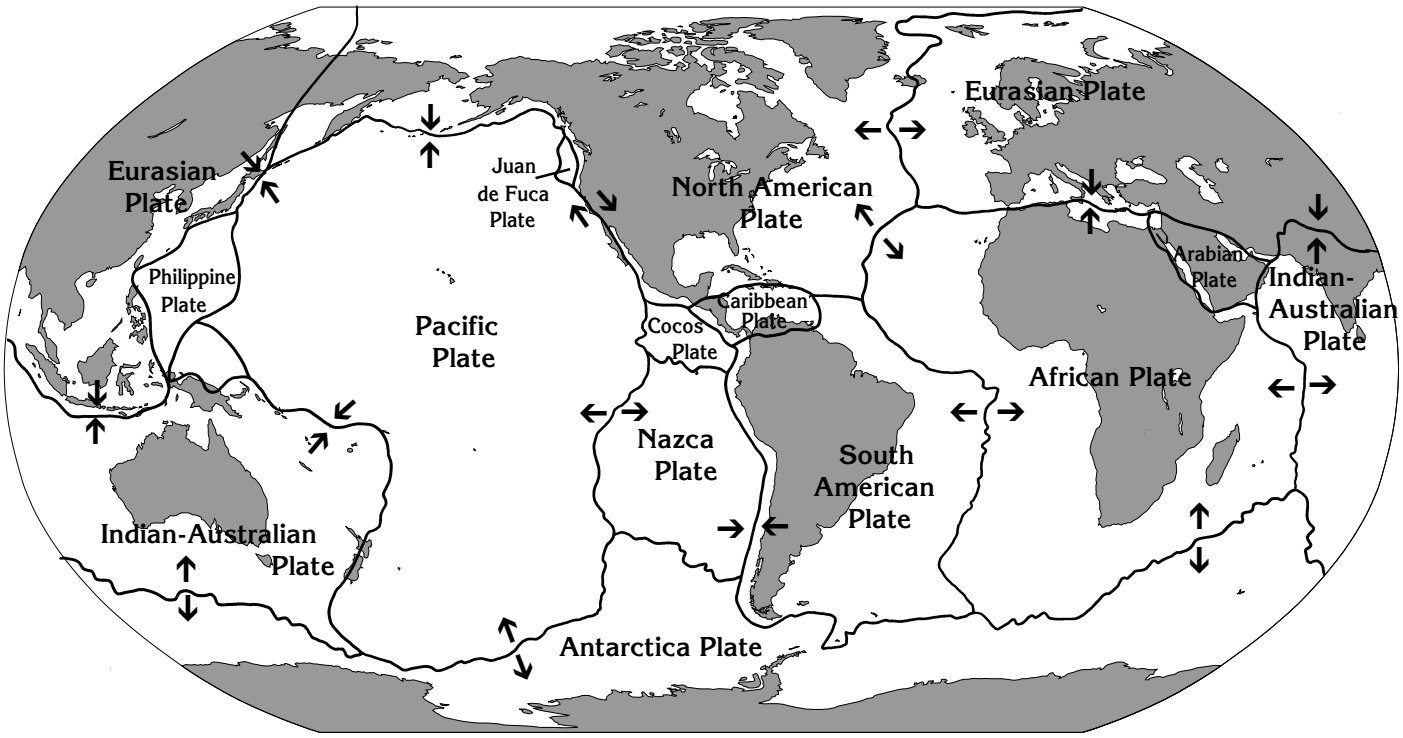


Plate Tectonics Theory

It is thought that the Earth has three layers: the crust, the mantle, and the core. The crust and upper part of the mantle are called the lithosphere or rock sphere. Below it lies the asthenosphere, a layer of semi-molten rock.

According to the plate tectonics theory developed in 1968, cracks split the Earth's crust into several major plates and a number of smaller plates, all of which float on the asthenosphere. The plates move by colliding, separating, or sliding, changing their positions just a few centimeters each year. Earthquakes and volcanic eruptions take place along the edges of these plates.



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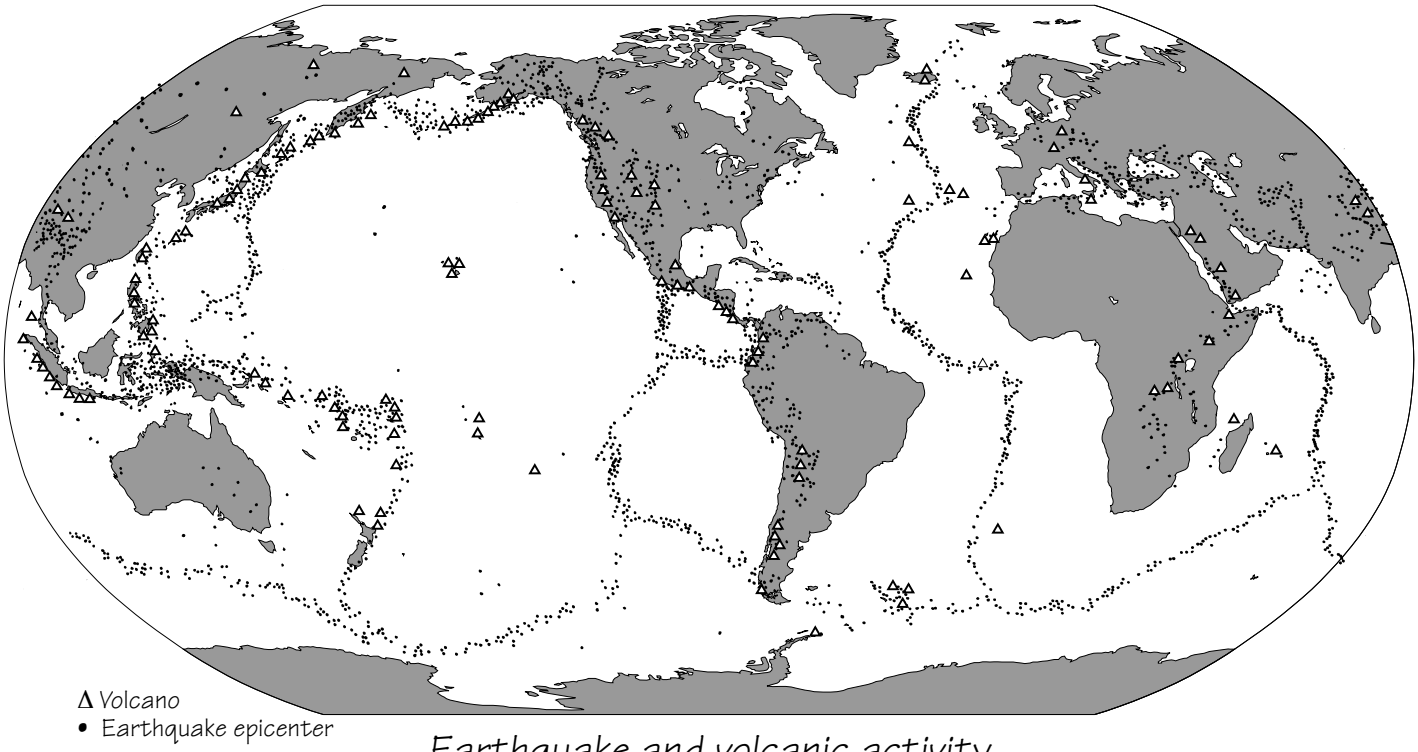
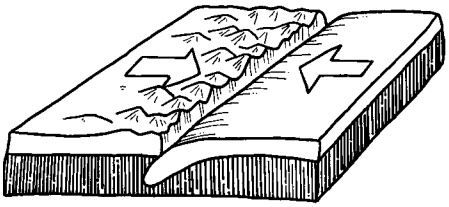
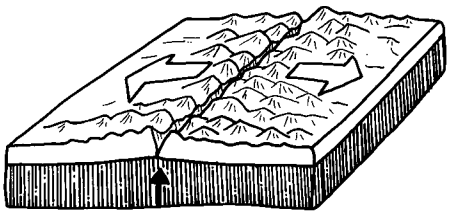


Earthquake and volcanic activity

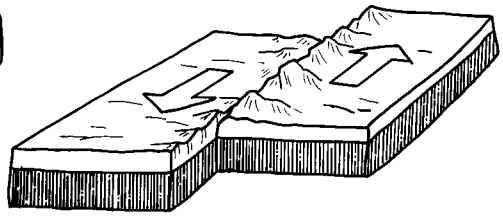
Plate Movement



colliding



separating



sliding

Collisions take place along some plate boundaries. When this happens, one of the plates may descend beneath the other one, with pieces breaking off and becoming part of the molten asthenosphere. This motion, called *subduction*, causes the upper plate to be lifted and folded, forming mountain ranges. India is presently going under Asia, creating the Earth's greatest mountain range, the Himalayas.

Mid-ocean ridges, where the crust in thinner than on the continents, tend to have plate boundaries that are separating or spreading apart. The gaps are filled with partially molten rock rising from the asthenosphere. The hot material spreads and slowly cools. The Mid-Atlantic Ridge, a mountain range rising about

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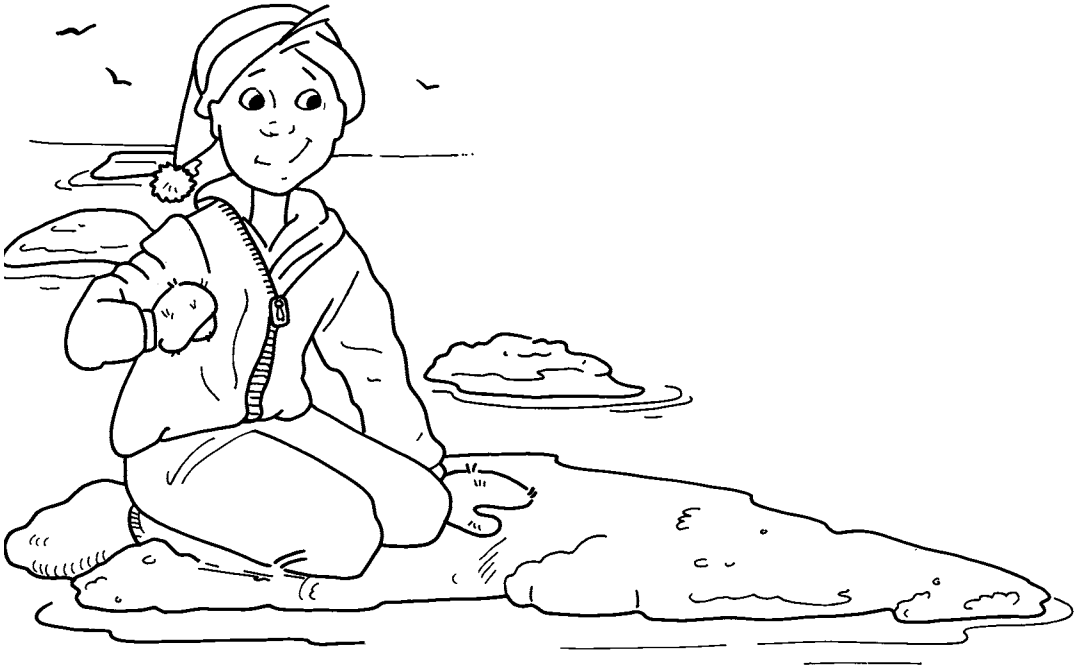
3,000 meters (10,000 feet) above the ocean floor is one place where *sea spreading* is occuring. The total surface area of the Earth does not change so, while new crust is being formed at the mid-ocean ridges, other pieces of crust are breaking off and becoming part of the asthenosphere at collision boundaries.

At other boundaries, plates move by sliding past each other. The Pacific Plate is moving northward in this fashion, along the San Andreas Fault.

What drives the movement of the plates? Scientists are not sure. A leading explanation is that the unequal distribution of heat causes convection currents in the mantle. The semi-molten asthenosphere rises with heat, causing the plates to separate while collisions at other plate boundaries cause pieces of rock to break and sink back into the asthenosphere. Scientists continue to search for clues that will explain what causes the plates to move.

Evidence suggests that the continents have come together, then drifted apart several times during Earth's history, though not necessarily at the same rates or with the same results we have today. Pangaea is just the most recent joining of the continents. The cycle is expected to continue.



1. de Blij, Harm. *Harm de Blij's Geography Book*. John Wiley & Sons, Inc. New York. 1995.
2. Lutgens, Frederick K. and Tarbuck, Edward J. *Essentials of Geology*. Merrill Pub. Co. Columbus, Ohio. 1989.

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ACTIVITY

EARTH FORCES

Topic
Force

Key Question
What are the effects of the push and pull forces that move the tectonic plates that cover the Earth?

Learning Goals
Students will:
1. use a map to identify the plates that cover the surface of the Earth, and
2. explore the effect of forces at convergent, divergent, and transform plate boundaries using a hands-on manipulative.

Guiding Documents
Project 2061 Benchmarks
- *Something that is moving may move steadily or change its direction. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.*
- *How fast things move differs greatly. Some things are so slow that their journey takes a long time; others move too fast for people to even see them.*

NRC Standards
- *The position of an object can be described by locating it relative to another object or the background (reference frame).*
- *An object's motion can be described by tracing and measuring its position over time.*
- *The position and motion of objects can be changed by pushing or pulling (first law). The size of the change is related to the strength of the push or pull (second law).*
- *The solid earth is layered with a lithosphere; hot, convecting mantle, and dense, metallic core.*
- *Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.*
- *Land forms are the result of a combination of constructive and destructive forces. Constructive forces including crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.*

Science
Physical science
  balanced and unbalanced forces
Earth science
  plate tectonics

Integrated Processes
Observing
Comparing and contrasting
Seeing relationships
Using models

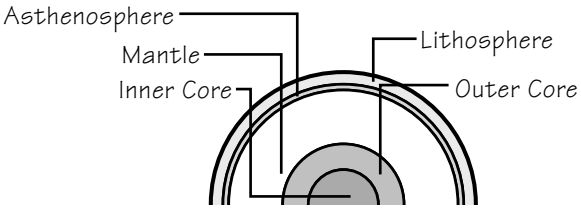
Materials
Card stock, 8.5" x 11"
Paper towels
Transparent tape

Background Information
In 1912, Alfred Wegener (1880–1930) noticed (as had others) that the east coast of South America seems to fit, like a puzzle piece, into the coast of West Africa. Checking other locations and finding similar fits, Wegener put forth the hypothesis that all of the continents were once part of a single super-continent he called Pangaea ("all lands").

Wegener's hypothesis that the continents drifted apart over geologic time explained how the leading edges of the drifting continents could collide and fold upwards to form mountains and how the same fossilized plants (from the same time period) were found in South America and Africa.

Prevailing scientific theory at the time was that the Earth was essentially solid. With a solid Earth, Wegener was unable to provide a mechanism that created the forces that pushed the continents around.

Around 1930, Arthur Holmes suggested that there are thermal (heat) convection currents in the asthenosphere (the softer, flowing, material under the lithosphere) and that these currents could move the plates (lithosphere).



The Earth

Over the years, evidence to support convection currents in the asthenosphere accumulated to the point that in the early 1960s, Howard Hess and Robert Deitz published convincing evidence that these convection currents do exist.

Some scientists theorize that the source of the heat that generates the convection currents is the radioactive decay of uranium and other radioactive elements located deep in the Earth.

The interactions between plates are generally classified in one of three ways: transform, divergent, or convergent. These three different interactions result in different types of features that form in the lithosphere.

At a *transform* boundary, two plates are sliding past each other. The San Andreas Fault of California is a classic example of this type of plate boundary. Earthquakes are often associated with this type of plate interaction.

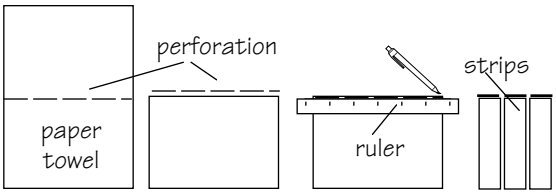
A *divergent* boundary occurs when two plates are moving apart from each other. Most divergent boundaries occur between oceanic crust and oceanic crust. These movements result in the formation of new crust. The Mid-Atlantic Ridge is a good example of this type of plate movement. The divergent movement between continental crusts is also forming the Red Sea between Africa and the Arabian Peninsula.

A *convergent* boundary is the third type of interaction that can occur between plates. A convergent boundary can be oceanic crust colliding with oceanic crust, oceanic crust colliding with continental crust, or continental crust colliding with continental crust. All three result in different features.

1. The first type of interaction is between oceanic crust and oceanic crust. This pushing of the plates together forms deep ocean trenches. Volcanic islands often form near these trenches.
2. When oceanic crust collides with continental crust, the oceanic crust is pushed down below the continental crust. This forces the oceanic crust down into the asthenosphere where it melts. This feature is called a subduction zone. This melted material pushes back up through the lithosphere forming volcanic mountains. The Cascade Mountain Range on the west coast of the United States is a classic example of this type of plate interaction.
3. Mountain building occurs when continental crust collides with continental crust. The Himalayan Mountains are a result of this type of convergent boundary.

Management

1. The purpose of this activity is to help students understand how the forces that act on tectonic plates at a boundary can produce the changes in the plates as observed and measured by geologists. With the focus on the interaction of the forces, the activity best supplements a broader unit of study about plate tectonics.
2. Make copies of the *Map of the Tectonic Plates* and *Tectonic Plate Forces* pages on card stock. You may want to laminate the pages and use them from year to year. You may also want to save the student pages as they make for a quick review of plate tectonics.
3. Strips of perforated paper toweling are used to explore the forces at a transform boundary. To make the strips, separate a 2-section piece of toweling from the roll. Fold the piece in half, along the perforation. Darken the perforated edge with a marker and cut into 3" or 4" strips. Each student will need one strip.

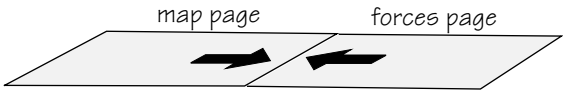


Procedure

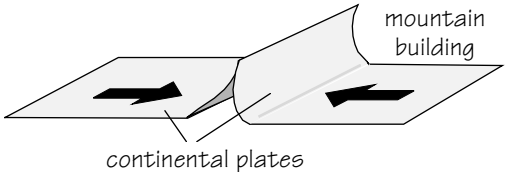
1. Distribute the *Map of the Tectonic Plates* and *Tectonic Plate Forces* pages.
2. Teach or review the basic concepts of plate tectonics (see *Background Information)*.

Forces at a Convergent Boundary

3. Instruct the students to place both student pages flat on the top of the desk so that the short sides touch. Tell the students that the two pages represent two tectonic plates meeting at a convergent boundary.

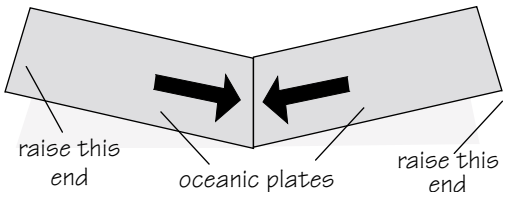


4. The forces at a convergent boundary collide head-on, so tell the students to push the two "plates" together along the boundary, and observe that the plates lift up.

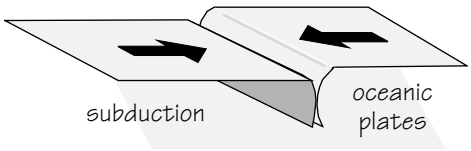


Tell the students that this illustrates how forces at a convergent boundary can build mountains where continental plates meet.

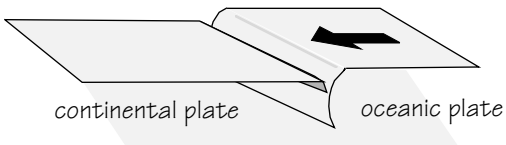
5. Instruct the students to again place both student pages flat on the top of the desk so that the short sides touch. Instruct them to lift the end of each page and to then push against the boundary.



Tell the students to observe that the colliding forces can produce a downward motion of the plates. Identify this process as subduction.

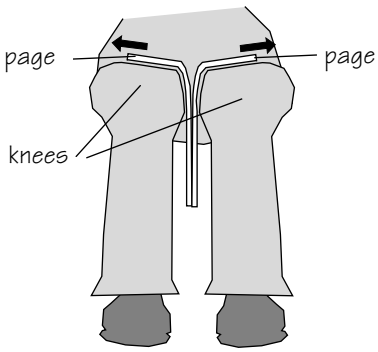


6. Challenge the students to hold one of the pages rigid (representing the continental plate), but still push against the other page (the oceanic plate), so that the oceanic plate slides under the continental plate.

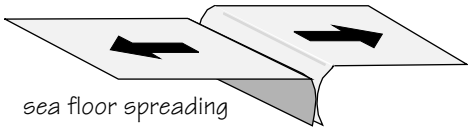


Forces at a Divergent Boundary

7. Instruct the students to place the two pages face to face, between the knees, with three to four inches of the tops of the pages above the knees.



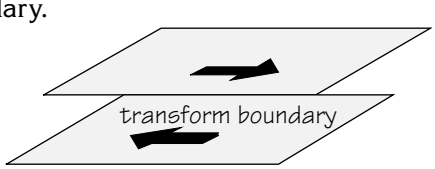
8. Tell them to pull each page to the side, in opposite directions, keeping the knees clamped on the pages, and observe that new material (the newly exposed surfaces of the pages) rises from below and moves, in opposite directions, to the sides.



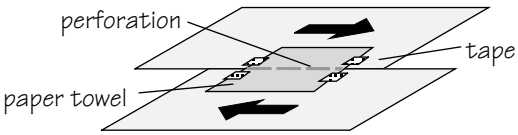
Tell the students that this illustrates how forces at a divergent boundary can bring new oceanic crust up from the asthenosphere.

Forces at a Transform Boundary

9. Instruct the students to place the two pages next to each other, long side to long side. Tell the students that the pages represent two tectonic plates at a transform boundary. Inform the students that the forces acting on the plates push the plates in opposite directions, along the boundary.



10. Distribute one strip of paper towel to each student. Demonstrate for the students how to tape the piece of paper towel across the transform boundary, so that the perforated edge runs along the boundary.



Have them slide the pages and explain that the towel pulling apart along the perforated line is similar to how the continental crust can break along the fault line at a transform boundary.

Discussion

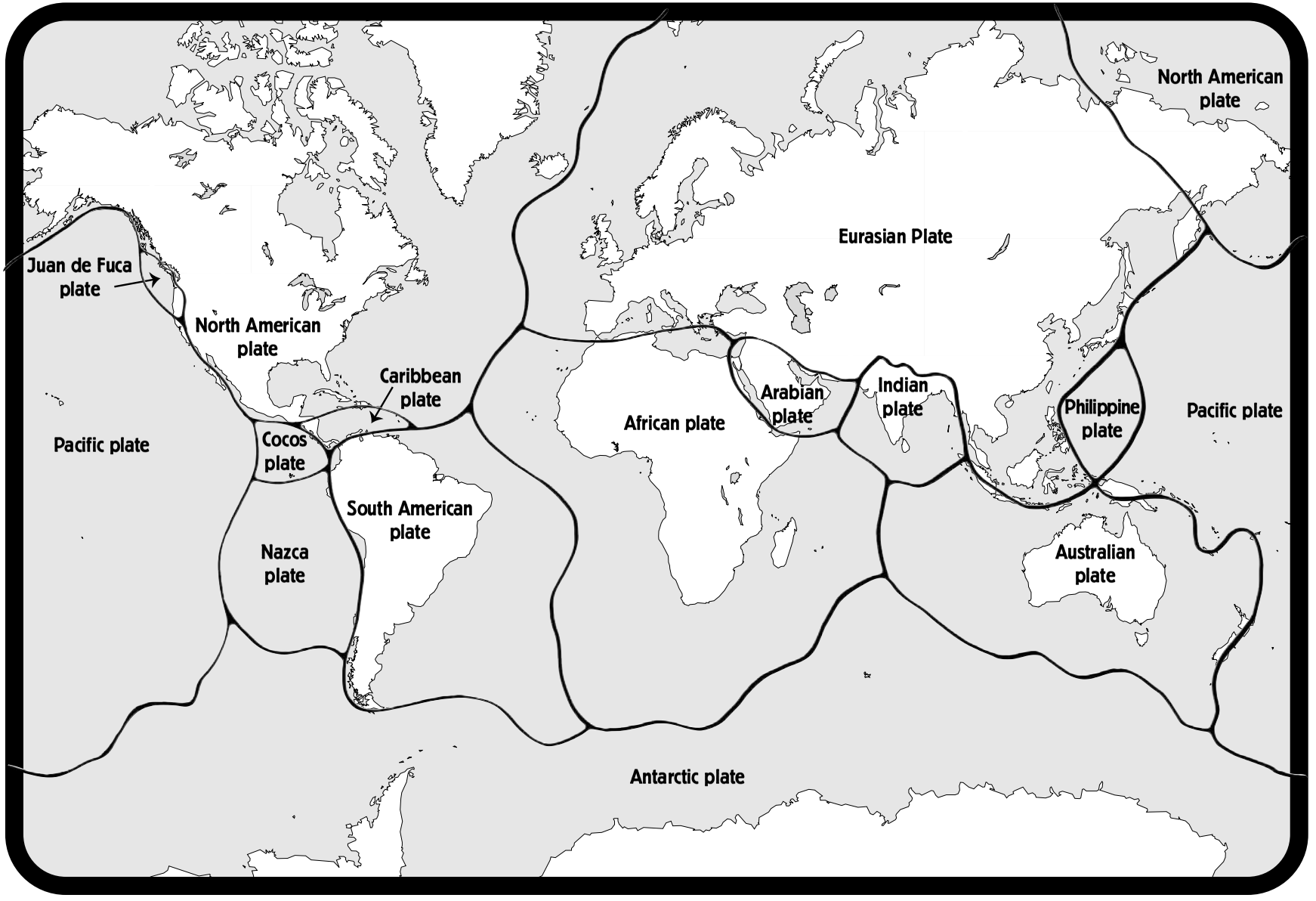
1. What happens when two continental plates collide? [mountain building occurs]
2. Where do you think there is evidence of this?
3. What happens when either two oceanic plates or an oceanic and a continental plate collide? [mountains are formed]
4. Where would you find evidence of mountain building because of the colliding of an oceanic plate and a continental plate? Explain how you decided this. [Mount St. Helens, Cascade Mountain range]

5. What happens when an oceanic plate collides with a continental plate? [The oceanic plate slides under the continental plate.]
6. What happens to oceanic crust at a divergent boundary? [New crust is formed from material taken from the asthenosphere.]
7. What happened to the strip of paper towel when you pushed the plates in opposite directions along the boundary? [The paper towel broke along the perforation.]
8. How is the perforation in the paper towel like a fault line? [The perorated line is the weakest part of the paper towel just like a fault line is the weakest part of the crust at a transform boundary.]
9. What are you wondering now?

Extensions

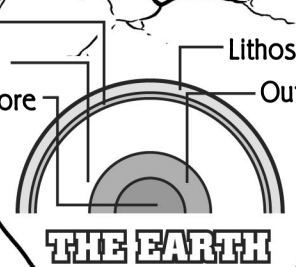
1. Have students research plate tectonics and identify the three kinds of boundaries on the *Map of the Tectonic Plates* page.
2. For a related plate tectonics activity, see *Plotting the Evidence* in Volume XV, Number 7 of *AIMS®*.

MAP OF THE TECTONIC PLATES



TECTONIC PLATE FORCES

Tectonic plates are sections of the lithosphere. These plates ride on top of the athenosphere and can move relative to each other.



CONVERGENT BOUNDARY

- where two tectonic plates push into one another
  - crust can be melted
  - crust can be pushed up
- crust types: continental and oceanic

continental meets continental — mountain building

continental meets oceanic
oceanic meets oceanic — subduction zones

- earthquakes and volcanoes

TRANSFORM BOUNDARY

- where two tectonic plates slide past each other horizontally
- crust is neither melted nor formed
- fault lines and earthquakes

DIVERGENT BOUNDARY

- where two tectonic plates move away from each other
- new crust is formed
- sea-floor spreading
- molten rock (magma) rises to create new oceanic lithoshphere
- rift valley systems

LAYERS of the Earth

Topic
Layers of the Earth

Key Questions
What does the interior of the Earth look like?
How do models help us understand things we cannot see directly?

Focus
Students will use a collaborative approach in solving clues to correctly construct, draw, and label the layers of the Earth. Each group will construct a "slice" of the Earth, and using a collaborative group effort they will construct a two-dimensional model of the Earth's interior structure. They will discover and discuss the use of models in science.

Guiding Documents
Project 2061 Benchmarks
- *Models are often used to think about processes that happen too slowly, too quickly, or on too small or large a scale to observe directly.*
- *Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.*

NRC Standard
- *The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.*

NCTM Standards
- *Apply estimation in working with quantities, measurement, computation, and problem solving*
- *Estimate, make and use measurements to describe and compare phenomena*

Math
Geometry and spatial sense
Measurement
  length

Science
Earth science
  geology
    layers of the Earth

Integrated Processes
Observing
Interpreting data
Applying
Generalizing
Comparing and contrasting

Materials
For each group of students:
  15 brown centicubes
  15 yellow centicubes
  15 orange centicubes
  15 red centicubes
  1 protractor
  1 piece of chart paper
  colored markers or crayons
  calculator
  two paper clips
  thread or lightweight string

Background Information
Geologists theorize that the Earth's matter is distributed in layers. If we could drill all the way from the Earth's surface to its center, we would find that each of these layers is not uniform in thickness, physical properties, or composition. First we would drill through the *crust*, the thinnest part of the upper layer. The crust varies in thickness from 5 km for Oceanic Crust to 40 km for Continental Crust. Both of these along with the next 60 km are called the *lithosphere*. The thickness of the lithosphere is about 100 km. The lithosphere is composed mostly of granite and basalt. The *mantle* is the next layer we would come to. The mantle is thought to have a thickness of about 2800 km. The composition of the mantle is thought to be made up of rock that is denser than rock found in the lithosphere. This layer is thought to be composed of ultramafic rocks such as peridotite. The rock materials in this layer sometimes act as a solid and at other times like a liquid. The center of the Earth contains the *core*. The core can be thought of as being a ball with two distinct layers. Both layers are probably made up of iron and nickel. The outer layer is most likely liquid and the inner layer solid.

Management
1. Divide students into collaborative teams of four.
2. Prepare a set of *Geologists' Clue Cards* for each group. Make sure students know the meaning of radius and diameter.

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3. Inform the class of the rule that each student reads his/her clue to the group. Other students cannot read each other's clues.
4. Students will make "core samples" from centicubes. They will then construct a paper slice of the Earth's layers. The size of the slice will depend on the number of groups in the class. Three hundred and sixty degrees divided by the number of groups will give the size of the slice. If there were six groups, each group would use a slice made with a 60 degree angle (360 degrees divided by 6).
5. The students will construct paper clip and thread compasses. The "compass" is constructed by tying a piece of thread (or lightweight string) between two small paper clips. The total length of the "compass" will be equal to the radius of the paper slice model.

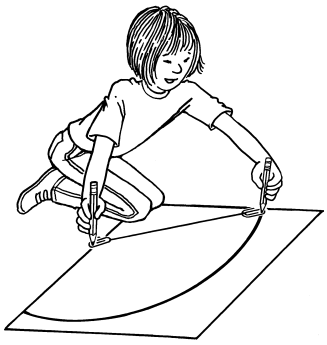
Procedure

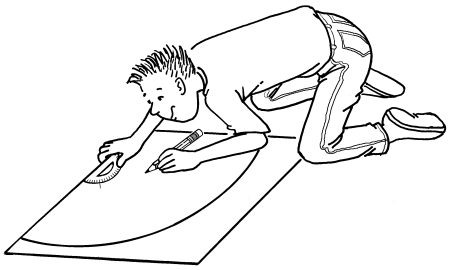
Part 1

1. Divide students into collaborative teams of four. Give each student one clue card.
2. Direct them to read the information on the card so the group can correctly construct the core sample made of centicubes. Remind them that the student holding the card can only read what's on his/her card; other students are not allowed to read each other's clues.
3. When all groups have completed the core sample, have them compare their core samples. Allow time for them to use the clues to check for accuracy.
4. Have the students draw and label the completed layer on the student sheet.

Part 2

1. Have each collaborative group construct a paper slice of the Earth's layers. (The number of student groups will determine the number of slices and the angle needed for each slice. See *Management 4.)*
2. Inform the students that they first must determine a scale for constructing the slices. (A large piece of chart paper allows them to use the scale 1 cm = 100 km.)
3. Have students construct the paper clip and thread compasses. (If using the 1 cm = 100 km scale, the compass should be 64 cm long from the end of one paper clip to the end of the other. Here's the procedure: Divide 12,800 km (diameter) by 2 to find the radius. This equals 6,400 km. If 1 cm = 100 km, then the string compass needs to be 64 cm.) Once the arc of the circle is drawn, direct students to place a protractor at the center point and align the straight edge of the protractor with the straight edge of the paper.





Now have them measure the appropriate angle for each slice of the Earth and use a meter stick to extend the line. This constitutes their slice.

4. To make each layer, have the students adjust the length of their paper clip and thread compasses. Tell them to always start their arcs at the center point.
5. As a class, determine a uniform key for the various layers and have each group color their slice of the Earth.

Part 3

1. Have the students use the clue cards again to determine the composition and the state of matter for each layer.
2. Direct them to label the layers on their slice of Earth.
3. Finally, have them illustrate and label their slice of the Earth on the back of their student page.
4. Gather all the groups' slices and put together the model of the layers of the Earth.

Discussion

1. What are the four layers of the Earth?
2. How accurate do you think this model is? Explain your thoughts.
3. What is the pattern when it comes to the order of states of matter in the layers? [solid, liquid, solid, liquid, solid] How can you account for this pattern? [Different materials have different melting points and the materials that are buried deep are under great pressure.]
4. Why are models useful in science?
5. What other models do you use in science? [globe, structure of atoms and molecules, the skeletal system, etc.]

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LAYERS of the Earth

Geologists' Clue Card One

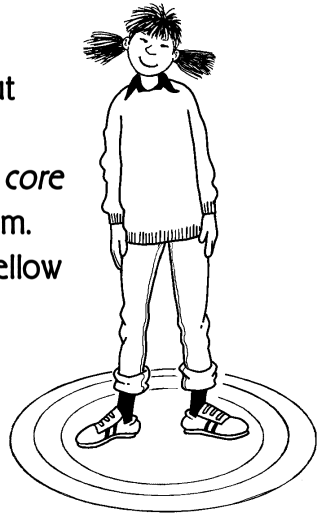
1. Scientists theorize that there are four layers that make up the crust of the Earth.
2. The *inner core* is most likely a solid.
3. The layer below the *lithosphere* is about 2800 km thick.
4. The layer below the *mantle* is liquid iron and nickel.

Geologists' Clue Card Two

1. The layer above the *inner core* is represented by the red centicube.
2. The *mantle* is the thickest layer; it is composed of peridotite.
3. Each centicube represents 200 km, but you will not need to use all the cubes given to you.
4. The *mantle* is a solid, but sometimes acts like a liquid near the portion that is directly below the *lithosphere.*

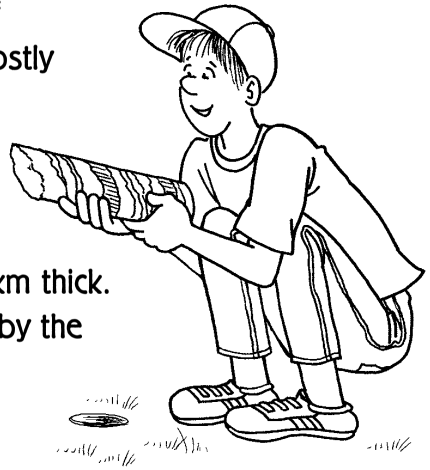
Geologists' Clue Card Three

1. The total diameter of the Earth is about 12,800 km.
2. The radius of the *inner core* and *outer core* when added together is about 3400 km.
3. The *inner core* is represented by the yellow cubes.
4. The top layer is called the *lithosphere.*



Geologists' Clue Card Four

1. The outer layer is composed of solid rock materials that are mostly granite and basalt.
2. The *inner core* and *outer core* both are made up of the same materials.
3. The *outer core* is about 2200 km thick.
4. The *lithosphere* is represented by the brown centicube.



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LAYERS of the Earth

Draw your core sample of the Earth.
Label each layer.

Labels to be used on your slice of the Earth.

Mantle	____ km thick
Lithosphere	____ km thick
Inner Core	____ km thick
Outer Core	____ km thick

Solid	Solid
Solid	Liquid
Liquid	Liquid
Basalt	Granite
Peridotite	Nickel
Iron	

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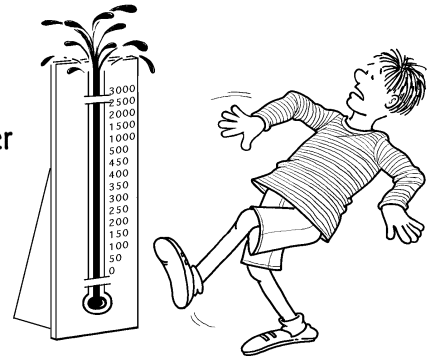
LAYERS of the Earth

Inner Core

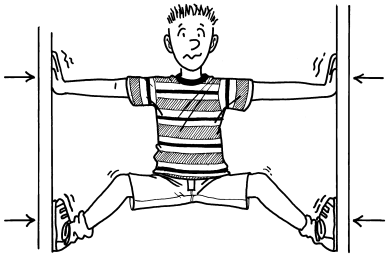
The inner core consists of the elements iron and nickel. The temperature in this region reaches 5000 degrees Celsius. Under normal circumstances with these high temperatures, nickel and iron would easily melt. The inner core however is under such great pressure that it pushes the particles of iron and nickel together to form a solid. Scientist theorize that the iron core of the Earth may explain the existence of the magnetic fields around the Earth. The inner core has a diameter of about 2600 kilometers.

Outer Core



The outer core consists of the elements iron and nickel. The outer core is part of a two-part core system. Scientist theorize that this region of the core is a liquid. The liquid nature of this layer is why scientist separate the core into a two-layer system. The outer core is about 2000 kilometers thick. Scientists think that this layer is probably composed of mostly nickel. The temperature of the outer core is about 3800 degrees Celsius. This layer is the thinnest of the three interior layers.

Mantle



The mantle makes up about 80% of the volume of the Earth and about 68% of the Earth's mass. It begins at a region about 100 kilometers below the surface of the Earth and extends down to 2900 kilometers. Scientists believe the mantle consists of the elements silicon, oxygen, iron, and magnesium. They theorize that the upper region of the mantle can flow like a thick liquid. The high temperature and pressure in the mantle allows the solid rock to flow slowly. Plasticity is the name given to a solid that has the ability to flow. At the top of the mantle is a region called the Moho. This area marks the boundary between the mantle and the crust.

Lithosphere

The top layer of the Earth is called the lithosphere. This layer is the thinnest of all the layers of the structure of the Earth. Most of the crust cannot be seen. It is covered with soil, rock, and minerals. The crust is made up of three different rock types: igneous rocks, sedimentary rocks, and metamorphic rocks. The thickness of the Earth's crust varies a great deal. The crust under the surface of the ocean is called oceanic crust. This is the region of the crust where it is thinnest. Oceanic crust is made up of basalt. The other type of crust, the continental crust, can be found under the continents. Continental crust is primarily composed of granite.

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PLOTTING THE EVIDENCE

Topic
Plate tectonics

Key Question
What do the locations of earthquakes and volcanoes tell us about the location of the Earth's lithospheric plates?

Learning Goals
Students will:
1. plot the latitude and longitude for earthquakes and volcanoes;
2. examine patterns of earthquake and volcanic activity; and
3. infer location of the lithospheric plates based on evidence.

Guiding Documents
Project 2061 Benchmarks
- *The solid crust of the earth—including both the continents and the ocean basins—consists of separate plates that ride on a denser, hot, gradually deformable layer of the earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface of these plates may fold, forming mountain ranges.*
- *Earthquakes often occur along the boundaries between colliding plates, and the molten rock from below create pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.*

NRC Standards
- *Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.*

*NCTM Standards 2000 **
- *Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life*
- *Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots*
- *It takes two numbers to locate a point on a map or any other flat surface. The numbers may be two perpendicular distances from a point, or an angle and a distance from a point.*

Math
Geometry
  location
Data analysis
  graphing
Measuring

Science
Earth science
  geology

Social Sciences
Geography
  coordinate grid

Integrated Processes
Observing
Comparing and classifying
Relating
Communicating
Interpreting data
Inferring

Materials
For each group of students:
  one Mercator projection map (see *Management 2*)
  one new black and one new red overhead pen (see *Management 4*)
  one blank transparency
  one set of earthquake and volcano cards

For the class:
  one transparency of *Plate Boundaries*

Background Information
The outer shell of the Earth, consisting of the crust and the uppermost part of the mantle, is thought to be composed of interlocking segments called lithospheric plates. A plate is a large rigid slab of solid rock. The word *tectonics* comes from the Greek root "to build." When scientists use the term *plate tectonics* they are describing the Earth surface being made of plates. These plates are moving and are in constant interaction with each other. The interaction of the plates accounts for the vast majority of earthquakes as well as volcanoes on the surface of the Earth. The interaction between the plates results in other geologic features on the Earth such as mountains and deep open trenches.

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The focus of this activity is for students to see the evidence as a scientist would to infer the location of the plates based on where earthquakes and volcanoes occur. The map used in this activity is a Mercator projection, the polar regions are not shown and the high-latitude regions are distorted; therefore, the size of the plates are distorted.

Management

1. This activity is written for six groups.
2. Copy six of the world maps for the groups to use to plot the earthquakes and volcanoes.
3. Copy the plate map on transparency film.
4. It is best to use *new* extra-fine tip overhead pens when plotting the points on the maps. Stress for accuracy when plotting the points.
5. Copy the *Earthquake Plotting Data* and *Volcano Plotting Data*. Cut the six sets of data apart. Each group will get one section of the earthquake data and one section of the volcano data.

Procedure

1. Ask the *Key Question* and review the learning goals.
2. Distribute the maps, blank overhead transparencies, and pens. Review (or teach) how to plot latitude and longitude on the map. The latitude lines are the north/south lines and the longitude lines are the east/west lines. The latitude is listed first when listing positions on globes or maps.
3. Show the students how to position the transparency on the map and trace the cross hairs in the location circles.

   Remind the students as they are working to keep checking to see that the cross hairs are lined up when plotting the data.
4. Distribute the earthquake data, one section to each group. Have each group plot the location on the world map where each earthquake occurred with a single black dot.
5. When the groups have finished plotting the earthquake data, have them discuss any patterns they may see. (Most will not see any pattern, or if they do, it will be an isolated pattern.)
6. Tell the students that they may need more evidence. Distribute the volcano data and have each group plot the location of each volcano, by drawing a small triangle in red.
7. Ask the students if they see any patterns now. (Most will still not see any pattern.)
8. Ask the students if it would be better to have more data. Have each group bring their transparency with the plots and place them on the overhead. Make sure each group lines up the cross hair markings in the circles.
9. Ask the students if they see any patterns now? (Students may or may not see that earthquakes and volcanoes occur in some regions of the map more often than others.)
10. Tell the students that as a group they have plotted over 200 pieces of data. Tell them hundreds of earthquakes occur everyday. Scientist have plotted where they occur and have discovered that most earthquakes and volcanoes occur in very specific locations. Place the transparency of the Earth's plates on the overhead and ask the students what they notice. (Students should be able to see that most, but not all, earthquakes and volcanoes occur near plate boundaries.)
11. Make sure the students see that the plate boundaries do not match all continental boundaries.

Connecting Learning

1. What evidence do you have that would explain why the Australian continent has very few earthquakes?
2. Compare the earthquake activity and volcanic activity of the west and east coasts of South America. Why do you think these continental margins are so different?
3. Do earthquake and volcanoes only occur along the boundaries of plates? (The African Rift Valley, located near the east coast of Africa below the Horn of Africa, and the Hawaiian Islands in the Pacific are examples of where volcanoes and earthquakes occur that are not associated with a plate boundary).
4. There are mountain chains along the west coast of both North and South America. Why do you think there are mountains at these locations? [Interactions between plates often build mountains.]
5. Which plate seemed to have the most earthquake and volcanic activity? [The Pacific Plate accounts for about 81 percent of the world's largest earthquakes. This plate is often referred to as the Ring of Fire. This region extends from Chile, northward along the South American coast through Central America, Mexico, the West Coast of the United States, and the southern part of Alaska, through the Aleutian Islands to Japan, the Philippine Islands, New Guinea, the island groups of the Southwest Pacific, and to New Zealand.]

Evidence of Learning

1. Watch for accuracy in plotting the data for the earthquakes and volcanoes.
2. Listen for explanations during the *Connecting Learning* questions that use lines of evidence based on the activity.

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PLOTTING THE EVIDENCE

earthquake plotting data

GROUP 1 DATA

4.0 S,	76.9 W
50.7 N,	175.3 E
6.7 N,	126.8 E
10.4 S,	118.6 E
34.5 N,	137.4 E
58.5 N,	153.4 W
71.7 N,	2.5 W
31.7 N,	51.0 E
62.9 S,	158.0 W
33.5 N,	22.9 E
53.6 S,	140.9 E
44.7 N,	9.5 E
36.4 N,	71.1 E
39.0 N,	74.9 E
29.6 S,	179.0 W
13.1 N,	125.9 E
34.3 N,	23.2 E
13.5 N,	125.6 E
40.3 N,	29.8 W
0.1 N,	66.9 E
49.7 S,	48.3 E
13.2 S,	30.1 E
17.1 N,	75.4 E
35.4 S,	92.1 E
31.2 N,	148.3 E

GROUP 2 DATA

12.3 S,	167.2 E
44.5 N,	129.4 W
31.5 S,	76.5 E
21.1 S,	68.4 W
55.6 N,	162.4 E
17.9 N,	146.5 E
71.6 N,	1.5 W
24.5 N,	122.2 E
11.0 N,	57.5 E
52.7 N,	173.3 W
2.7 S,	125.7 E
36.9 N,	116.0 W
10.9 S,	165.7 E
81.9 N,	4.8 W
31.6 S,	178.1 W
54.3 N,	161.3 E
7.5 N,	77.5 W
12.6 S,	168.5 E
8.0 N,	126.4 E
57.2 N,	149.4 W
40.3 S,	65.1 E
10.3 S,	29.8 E
10.4 S,	89.4 E
3.3 N,	135.4 E
18.6 N,	122.1 E

GROUP 3 DATA

21.7 S,	169.5 E
41.3 S,	88.8 W
4.3 S,	105.6 W
0.4 N,	67.2 E
36.3 N,	28.1 E
71.6 N,	2.5 W
51.6 N,	173.3 W
40.6 N,	124.5 W
13.0 S,	166.9 E
40.5 S,	176.8 E
20.3 S,	68.1 W
43.4 N,	126.7 W
32.1 S,	72.3 W
18.9 S,	172.6 W
51.5 N,	130.5 W
3.7 S,	11.9 W
36.3 N,	140.1 E
13.6 N,	56.6 E
56.6 S,	25.3 W
17.7 S,	174.7 W
1.2 N,	30.1 E
3.2 N,	92.4 E
28.4 N,	77.4 E
45.7 S,	175.4 E
5.7 N,	128.2 E

GROUP 4 DATA

20.9 S,	179.0 W
51.4 N,	179.1 W
6.5 S,	124.7 E
57.0 N,	7.3 E
21.7 S,	170.4 E
9.0 S,	108.6 E
3.9 N,	125.8 E
40.3 N,	125.3 W
17.4 S,	113.8 W
38.7 S,	106.7 W
45.1 S,	90.5 E
44.5 S,	77.4 W
53.4 S,	111.4 W
18.2 S,	174.4 W
21.7 N,	142.9 E
49.0 S,	127.2 E
39.4 N,	39.4 E
5.3 S,	139.7 E
15.2 S,	70.6 W
31.8 S,	178.4 W
4.3 N,	34.1 E
13.4 N,	100.4 E
28.4 N,	60.1 E
49.7 S,	169.8 E
49.8 S,	145.3 E

GROUP 5 DATA

46.6 N,	145.4 E
41.8 N,	143.9 E
10.3 N,	103.5 W
38.6 N,	40.6 E
39.4 N,	121.6 W
57.7 S,	15.3 W
49.6 N,	126.3 W
19.3 N,	155.0 W
37.5 N,	141.4 E
28.9 N,	177.4 W
5.0 S,	145.1 E
52.2 N,	176.2 W
49.3 N,	123.5 W
38.9 N,	142.5 E
27.1 N,	100.3 E
56.5 N,	25.2 W
30.0 N,	38.0 W
3.0 N,	27.1 W
18.2 S,	10.0 W
42.5 S,	14.5 W
12.4 N,	34.3 E
23.6 N,	98.3 E
29.1 N,	129.1 E
58.7 S,	167.9 E
57.3 S,	156.3 E

GROUP 6 DATA

52.1 N,	175.8 E
38.7 N,	22.6 E
26.3 S,	27.3 E
34.3 N,	116.3 W
53.8 S,	141.5 E
50.1 S,	13.1 W
56.1 S,	11.3 W
59.1 S,	8.4 W
26.3 N,	115.6 W
57.2 S,	136.4 W
25.6 N,	142.5 E
7.8 N,	38.8 W
42.2 N,	90.5 E
43.7 N,	28.6 W
12.8 N,	87.3 W
57.9 S,	27.4 E
58.7 S,	3.2 E
64.3 S,	18.4 W
56.4 S,	34.3 W
51.7 S,	52.3 W
7.4 N,	30.4 E
28.7 N,	88.9 E
10.1 N,	143.7 E
62.8 S,	172.7 E
69.3 N,	13.3 W

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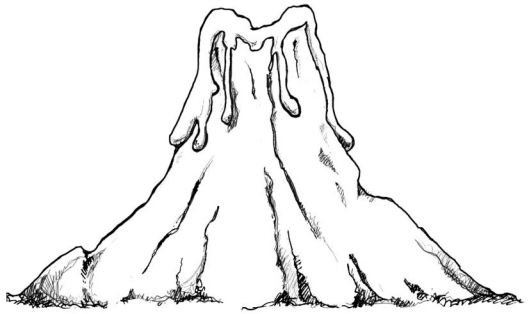
PLOTTING THE EVIDENCE

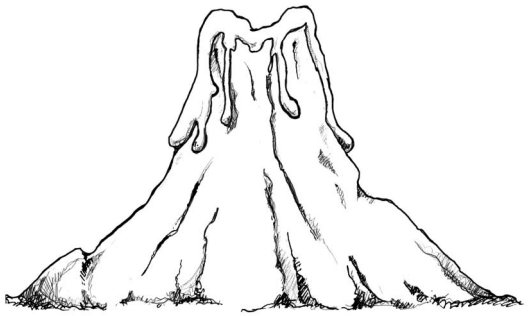
volcano plotting data

GROUP 1 DATA

Popocatepetl, Mexico
19.0N, 98.6W
Mount Ranier, United States
47.0N,122.1W
San Francisco Peaks, United States
35.1N, 112.2W
Piton de la Fournaise,
Island of Reunion
21.2S, 55.7E
Sakura-Jima, Japan
31.6N, 130.7E
Fuego, Guatemala
14.5N, 90.9W
Soufriere Hills,
Montserrat, West Indies
16.7N, 62.2W
Tavurvur, Papua New Guinea
4.3S, 152.2E
Mount Baker, United States
49.1N, 122.2W
Etna, Sicily, Italy
37.7N, 15.0E



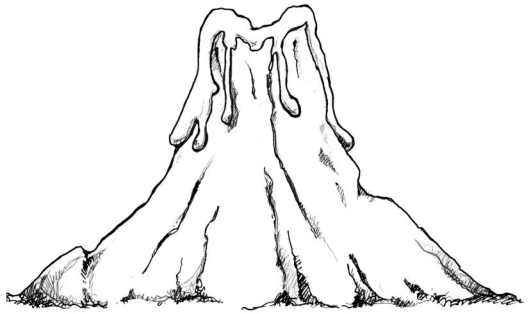
GROUP 2 DATA



Mount Baker, United States
49.2N, 122.0W
Sakurajima, Japan
32.1N, 133.3E
Arenal, Costa Rica
10.5N, 84.7W
Ulawun, New Britain, Papua
New Guinea
5.1S, 151.3E
Kaba, Sumatra, Indonesia
3.5S, 102.6E
White Island, New Zealand
37.5S, 177.2E
Sheveluch, Kamchatka, Russia
56.7N, 161.3E
Mayon, Philippines
13.3N, 123.7E
Semeru, Java, Indonesia
8.1S, 112.9E
Lascar, Chile
23.6S, 67.7W

GROUP 3 DATA

Guagua Pichincha, Ecuador
0.2S, 78.6W
Krakatau, Indonesia
6.1S, 105.4E
Mount Cameroon, Cameroon
4.2N, 9.2E
San Cristobal, Nicaragua
12.7N, 87.0W
Shishaldin, United States
54.8N, 163.9W
Usu, Japan
42.5N, 140.8E
Mount Pelee, Martinique
15.1N, 61.3W
Pacaya, Guatemala
14.4N, 90.6W
Hekla, Iceland
63.9N, 19.7W
Kilauea, United States
19.5N, 155.3W



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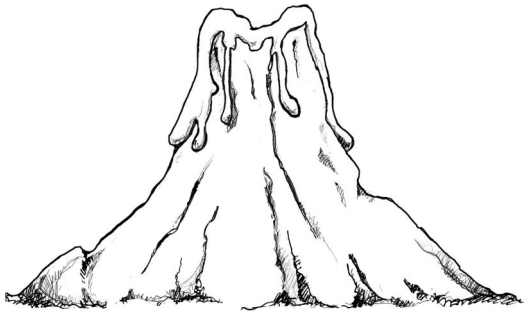
PLOTTING THE EVIDENCE

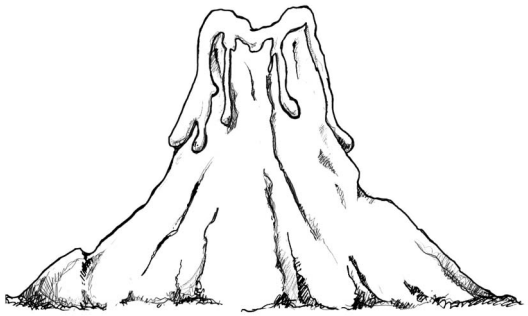
volcano plotting data

GROUP 4 DATA

Masaya, Nicaragua
12.0N, 86.2N
Colima, Mexico
19.5N, 103.6W
Taal, Philippines
14.1N, 120.9E
Ruapehu, New Zealand
39.3S, 175.6E
Unzen, Japan
33.2N, 133.1E
Mount Lewotobi, Indonesia
8.5S, 122.9E
Shishaldin, United States
54.8N, 163.9W
Lassen Peak, United States
40.1N, 122.1W
Terceira, Azores
38.7N, 27.3W
Surtsey, Iceland
63.1N, 19.4W



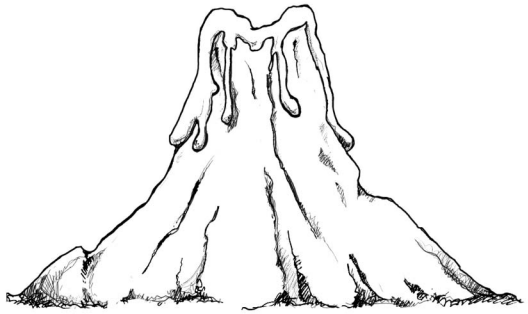
GROUP 5 DATA



Merapi, Indonesia
7.54S, 110.44E
Manam, Papua New Guinea
4.1S, 145.0E
Cerro Azul, Galapagos Islands,
0.90S, 91.42W
Stromboli, Italy
38.8N, 15.2E
Iwate-san, Japan
39.85N, 141.00E
Papandayan, Java, Indonesia
7.32S, 107.73E
Mount St. Helens, United States
46.20N, 122.18W
Korovin, United States
52.38N, 174.15W
Yellowstone, United States
44.43N, 110.67W
Mount Peuet, Indonesia
4.925N, 96.33E

GROUP 6 DATA

Rincon de la Vieja, Costa Rica
10.2N, 85.5W
Mount Karangetang, Indonesia
2.8N, 125.5E
Mount Kiliamanjaro, Tanzania
3.2S, 37.4E
Rabaul, Papua New Guinea
4.3S, 152.2E
Kliuchevskoi, Russia
56.1N, 160.6E
La Madera, Nicaragua
11.4N, 85.5W
Mount Fujiyama, Japan
35.3N, 139.0E
Momotombo, Nicaragua
12.4N, 86.5W
Akutan, United States
54.1N, 166.0W
Mount Pinatubo, Philippines
15.2N,120.2E



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Mercator Projection Map

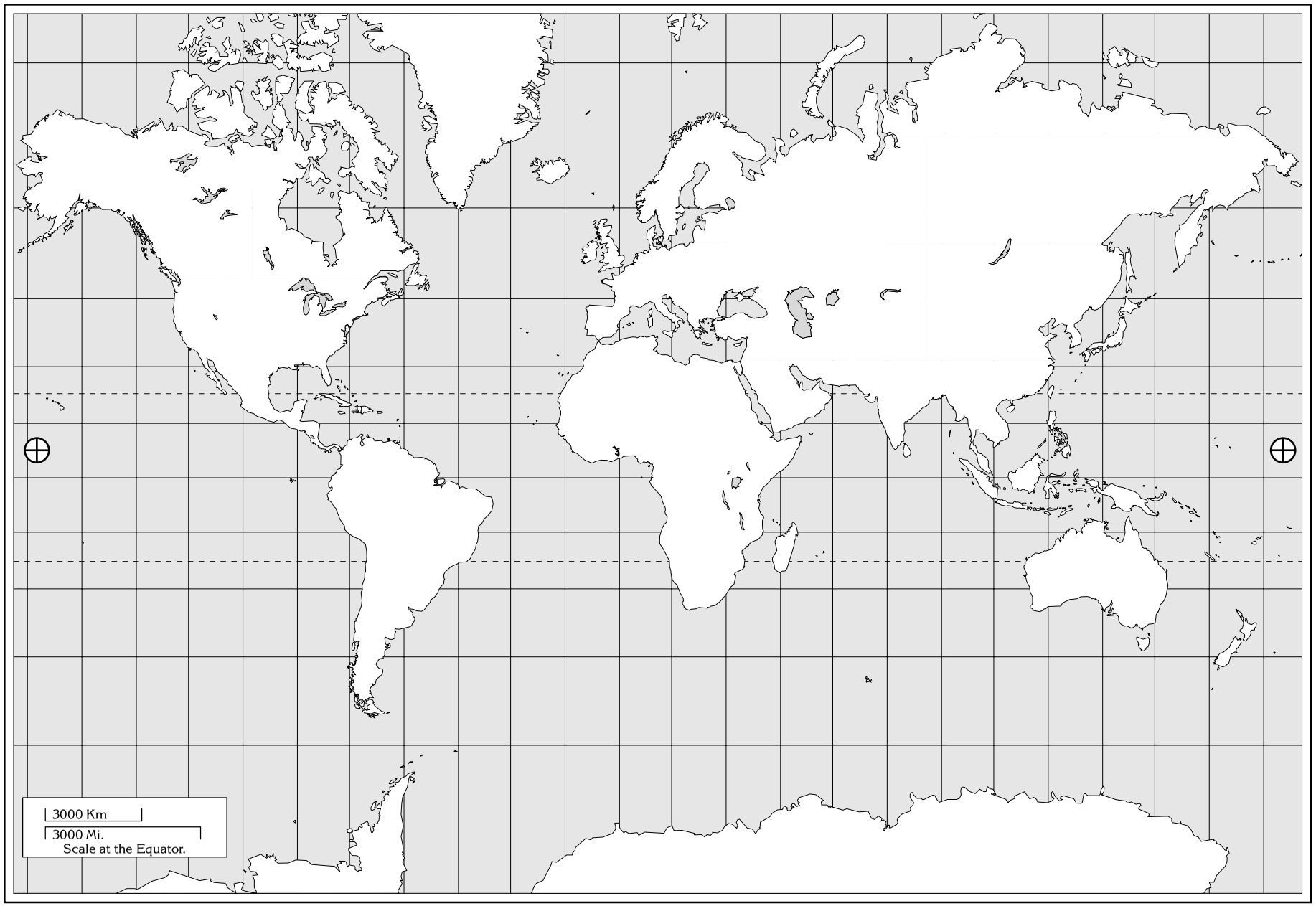

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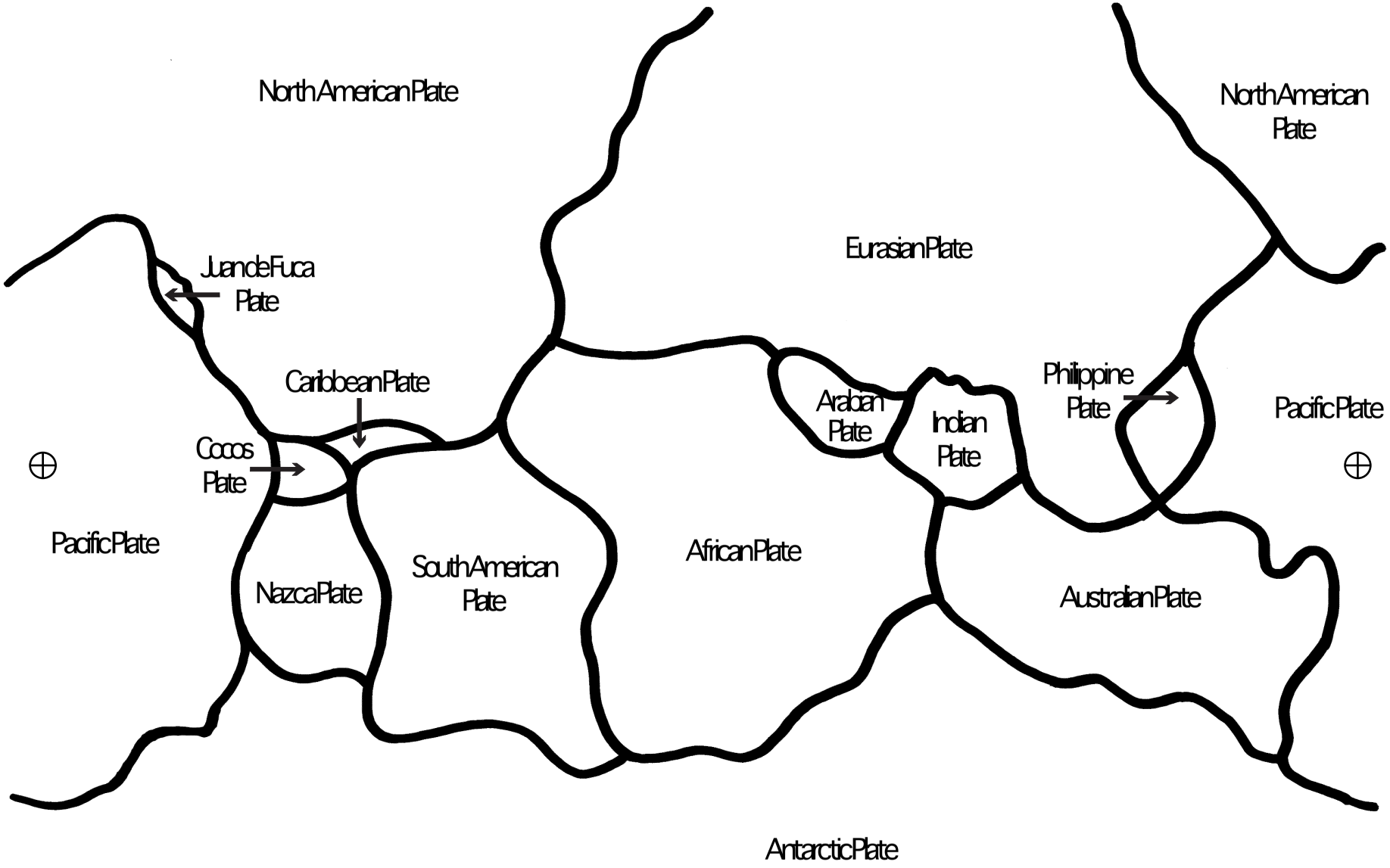
Plate Boundaries



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TOPPING OFF MOUNT SAINT HELENS

Topic
Topographical maps

Key Question
How can the steepness of geological features be shown on a flat map?

Focus
In this activity students will use contour maps to construct models of Mt. St. Helens before and after the 1980 eruption.

Guiding Documents
NCTM Standards
- *Explore problems and describe results using graphical, numerical, physical, algebraic, and verbal mathematical models or representations*

Project 2061 Benchmarks
- *Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains).*

Math
Scale drawing
Visualization skills
Topographical mapping

Science
Earth science
geology
volcanoes
mapping

Social Science
Geography
Topographical mapping

Integrated Processes
Observing
Comparing and contrasting
Generalizing

Materials
carbon paper
corrugated cardboard, 26 - 6"x 6" pieces per set of models
scissors or craft knives
glue
optional: paint

Background Information
A contour line on a topographical map shows all the points of equal elevation. If you were to follow one line around a mountain you would remain at a consistent elevation, neither going up or down.

Contour lines which appear to be very close together indicate a rapidly changing elevation. The corresponding area on the mountain will be steep. In contrast, lines which are further apart indicate a change in elevation that is more gradual and the corresponding slope is gentler.

The maps made by the U.S. Geological Survey (from which the maps in this activity have been taken) have been made using a technique called *photogrammetry*. In this technique two photographs are taken by a plane flying over an area. The photographs are very similar, but being taken from slightly different positions they have subtle differences. When the two photos are positioned under a viewer, the area takes on a three-dimensional perspective, much like what you see while looking through a stereoscope. The surveyor uses the three-dimensional perspective to draw in the contour lines.

The eruption of Mount St. Helens on May 18, 1980 lowered the mountain's height by 1,379 feet. The eruption left a crater 2400' deep and displaced 3,179,475,800 cubic yards of volcanic rock (0.5832 cubic miles). The eruption released 1.7×10^{18} joules. This is the equivalent of 27,000 Hiroshima-sized atomic bombs exploding over a nine hour period.

Management
1. Gather necessary cardboard before beginning. If you choose to have each group build a model, you may assign each group to gather their own cardboard. Use a paper cutter to cut it into 6" x 6" pieces.
2. This activity is designed as a class project. Each student is assigned one contour line to trace and cut out. Extra students can be assigned the jobs of gluing and assembly.
3. Craft knives make more accurate and easier cutting of the cardboard. You may find scissors are more easily accessible and less dangerous.

Procedure
1. Discuss the *Key Question* with the class.
2. Distribute student sheets and ask students how the contour lines might describe a mountain.
3. Distribute cardboard, carbon paper, and cutting tools.

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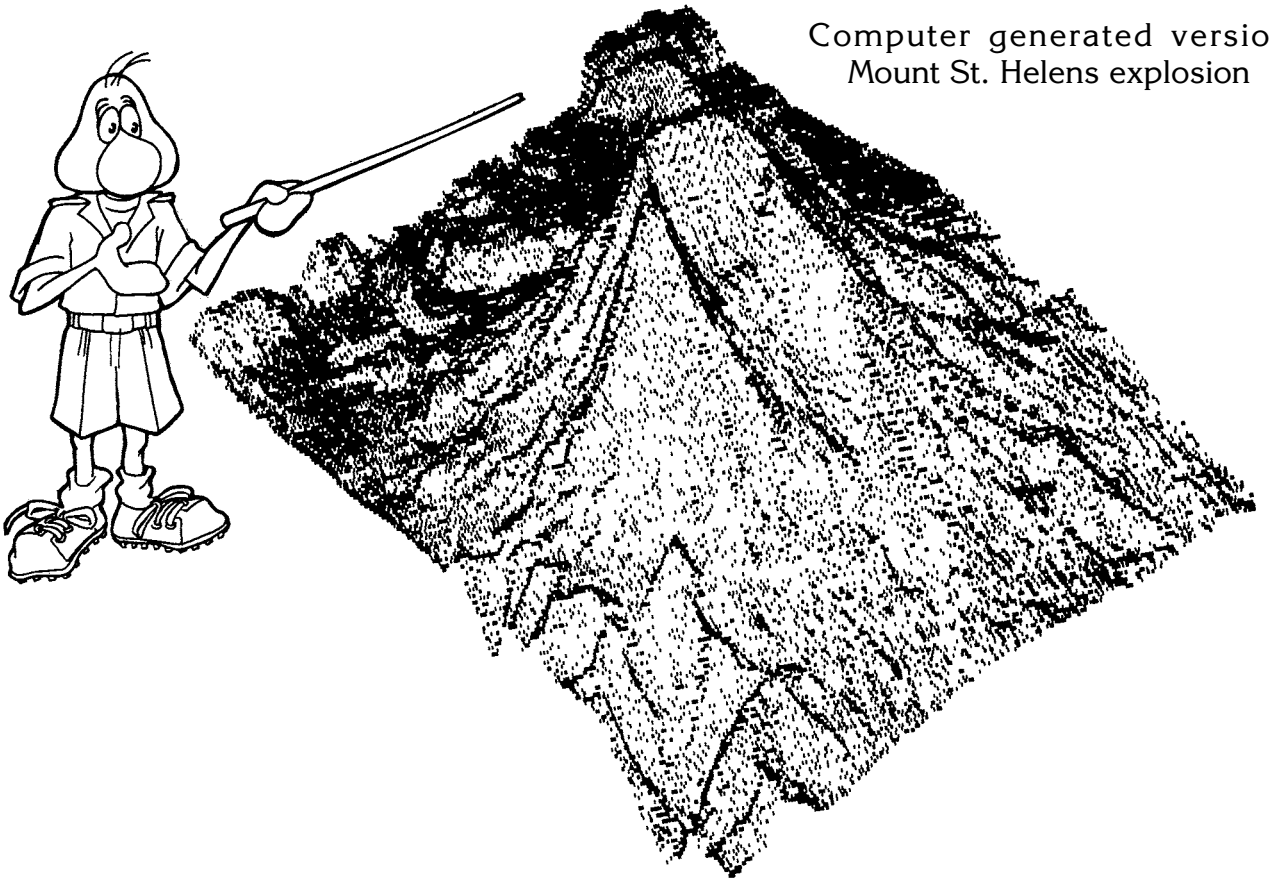
4. Assign each student one of the contour lines on one of the maps.
5. Direct students to use the carbon paper to trace their assigned contour line, and the next higher (smaller) contour line onto their cardboard. Be sure students have the carbon side of the paper facing the cardboard, and that the map and cardboard do not shift while they are tracing.
6. Have them cut the cardboard along their assigned contour line.
7. Glue the cardboard pieces together starting with the lowest contour piece. Glue on the next lowest piece using the carboned line on the lowest piece for placement. Continue gluing the pieces in sequence until you get to the highest piece.
8. When the models are dry, students may choose to paint them.

Discussion

1. How does the model compare to a picture of Mt. St. Helens?
2. How do the two models differ? [crater, height]
3. How do these differences show up on the map? [indentation of contour lines, less contour lines on map of shorter mountain]
4. Look at the steep sides of the crater on the second model. How does this steepness show up on the map? [contour lines are very close together]
5. Using the scale on your map and looking at the model mountains, estimate how much rock was moved to make the crater. [Answers will vary, but discuss strategies for estimating. You might take modeling clay to make the top of the original mountain on the crater of the new mountain, and then reform the clay into a cube and scale an edge. See *Background Information*.]

Extensions

1. Have students look at actual topographical maps and describe the lay of the land.
2. Get a topographical map of a local area and make a model using it.



Computer generated version of Mount St. Helens explosion

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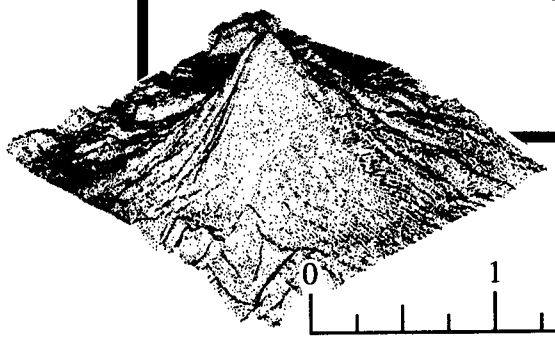
TOPPING OFF MOUNT SAINT HELENS

Before the 1980 Eruption



Source: Mt. St. Helens Quadrangle 15 Min. Series
Geological Survey
N4600-W12200/15
1958
Maximum Height 9677'

0 1 2

Scale: 1 inch = 1 mile

Contour Interval 400

GN MN

21 1/2 degrees

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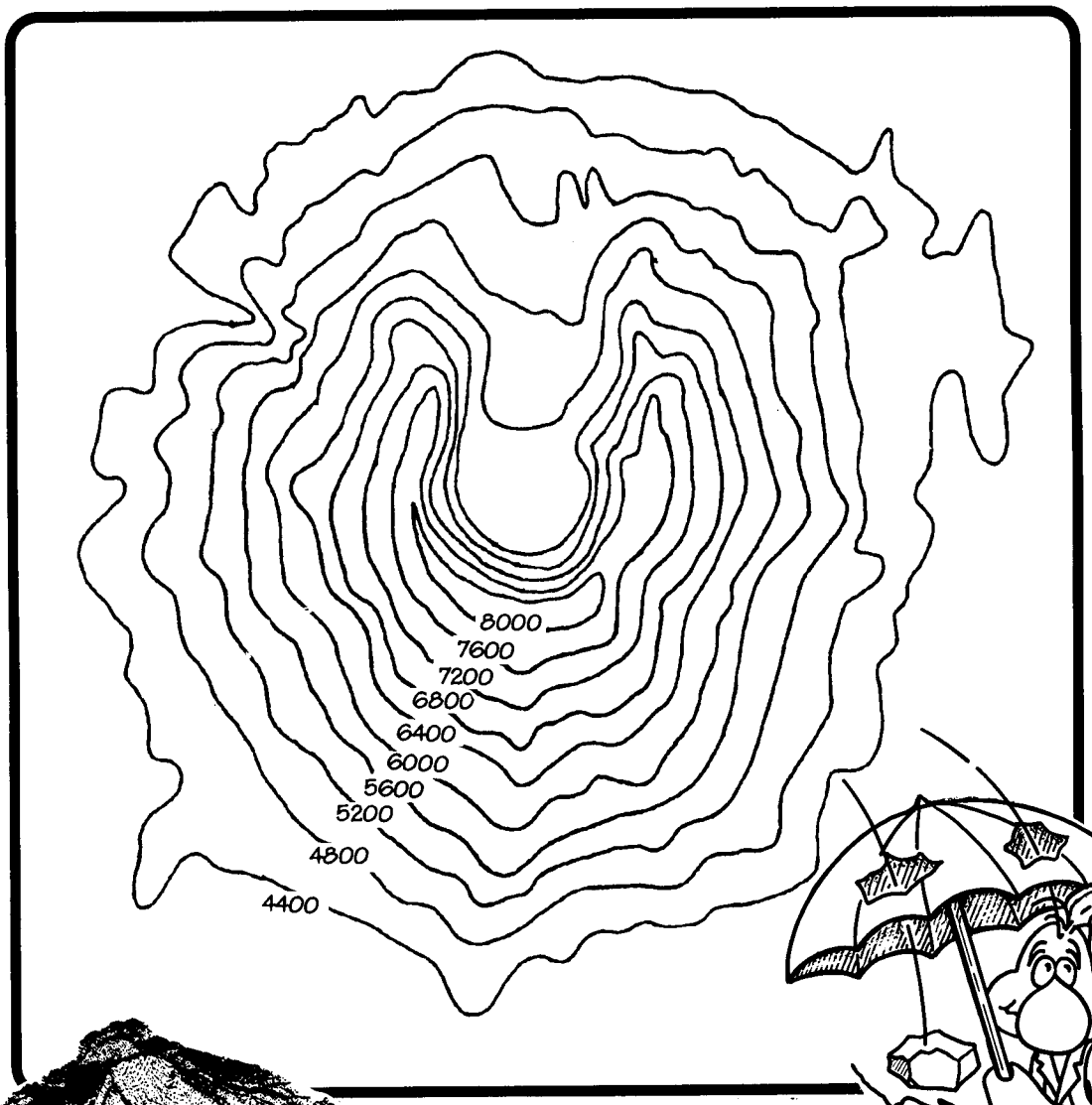
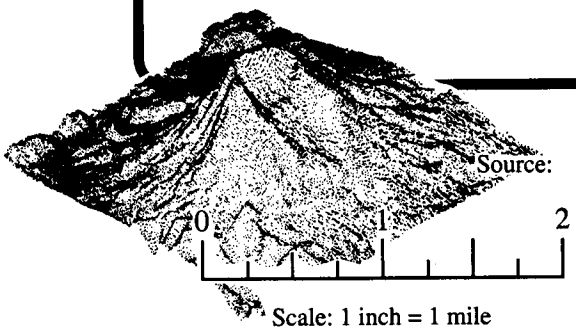
TOPPING OFF MOUNT SAINT HELENS

After the 1980 Eruption

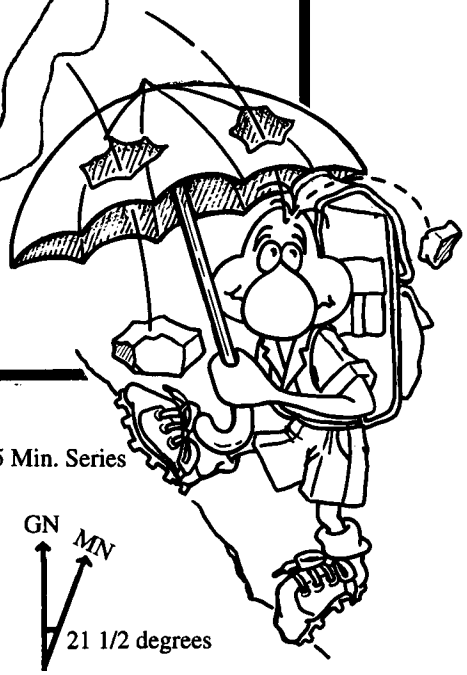




Scale: 1 inch = 1 mile

Contour Interval 400

Source:
Mt. St. Helens Quadrangle 7.5 Min. Series
Geological Survey
46122-B2-024
Provisional 1983
Maximum Height 8298'



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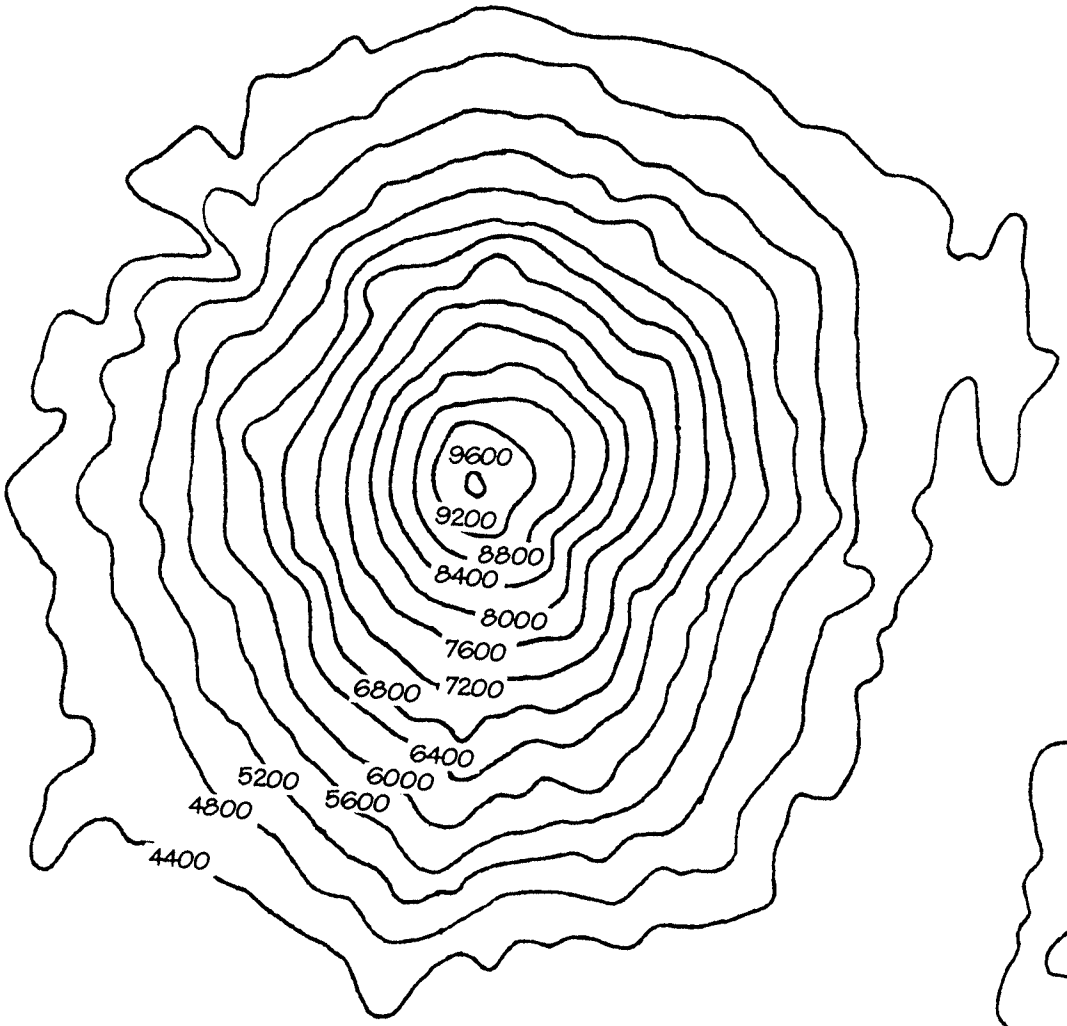
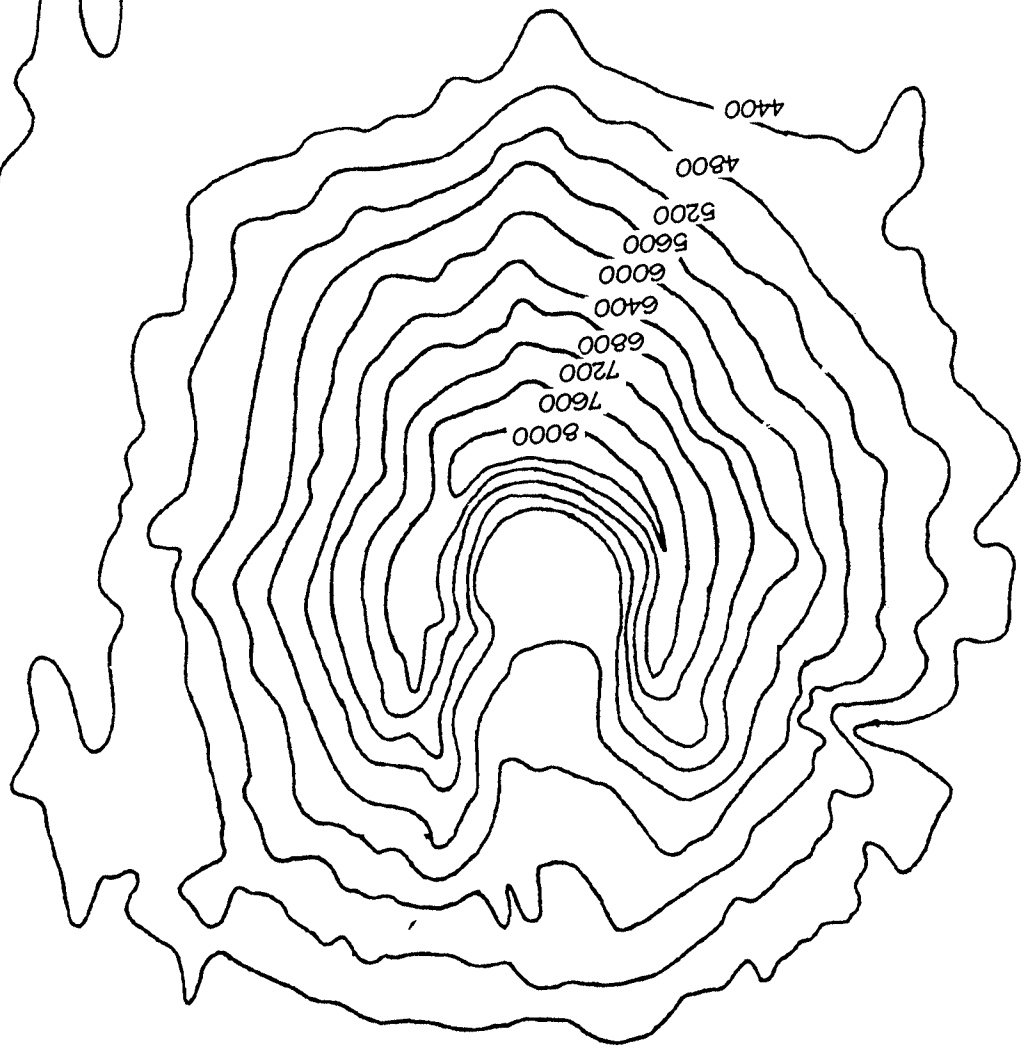


Before 1980



After 1980

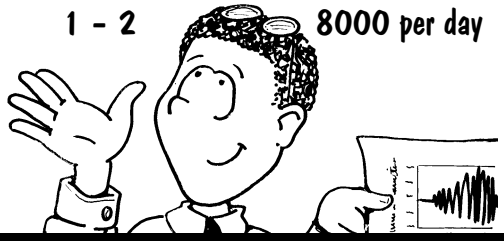
Topping Off Mount Saint Helens

Topping Off Mount Saint Helens

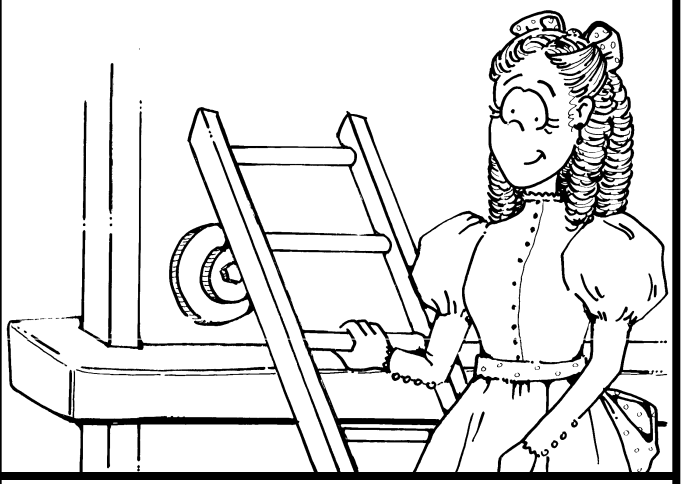
Isn't It Interesting...
Shaking Up the Facts

It is estimated by the USGS (United States Geological Survey) that several million earthquakes occur in the world every year. Here's their breakdown by magnitude:

Magnitude	Annual Average
8 and higher	1
7 - 7.9	18
6 - 6.9	120
5 - 5.9	800
4 - 4.9	6200 (estimated)
3 - 3.9	49,000 (estimated)
2 - 3	1000 per day
1 - 2	8000 per day



Many buildings in Charleston, SC have earthquake rods. These metal rods go through the building to hold it together. There are bolts on the ends of each rod that are visible on the outside walls of the buildings. Most rods were added after the earthquake of 1886.



Three earthquakes occurred in 1811 and 1812 near New Madrid, MO. They rank among the great earthquakes of known history. Judging from their effects, they were of a magnitude of 8.0 or higher on the Richter Scale.

The New Madrid earthquakes shook the entire United States. Large areas of land sank into the Earth, new lakes were formed, and the course of the Mississippi River was changed.

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Quake Quest

Topic
Earthquakes

Key Question
How can you locate the epicenter of an earthquake?

Learning Goals
Students will:
1. read simplified seismograms;
2. read and interpret a Richter Nomogram; and
3. interpret data to locate the epicenter of earthquakes using triangulation.

Guiding Documents
Project 2061 Benchmarks
- *Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplifting and wearing down mountains).*
- *Graphs can show a variety of possible relationships between two variables.*

NRC Standards
- *Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.*
- *Mathematics is important in all aspects of scientific inquiry.*
- *Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.*

*NCTM Standard 2000**
- *Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life*
- *Select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision*

Math
Measurement
  length

Science
Earth science
  geology

Integrated Processes
Observing
Inferring
Collecting and recording data
Interpreting data
Drawing conclusions

Materials
For each group
  one pushpin
  two scale compass cards (see *Management 5*)
  pencil with a sharp point
  one 12-inch by 18-inch piece of cardboard

Background Information

The study of earthquakes is called seismology. Earthquakes occur as a result of a sudden release of stored energy. This energy builds up over long periods of time as a result of forces between the Earth's tectonic plates. Most earthquakes occur along faults in the upper part of the Earth's crust when one tectonic plate moves rapidly relative to the position of the other plate. This sudden motion causes seismic waves to radiate out. This area is called the focus. This sudden motion can produce ground movement, which is referred to as an earthquake. A seismic wave transfers energy from one spot to another within the Earth. There are two types of waves that scientist monitor during earthquakes: P (primary) waves, which are similar to sound waves, and S (secondary) waves which is a type of shear wave. In the Earth P waves can travel through solids and liquids, and S waves can travel only through solids

Seismographs are instruments used to measure Earth movement. The first seismograph was created in the second century AD in China. The brilliant scientist, mathematician, and inventor Chang Heng developed this seismograph. The illustration on the student map page of this activity shows what this seismograph looked like. A tremor caused one of eight bronze balls that were placed in the dragon's mouth to drop into the mouth of one of eight bronze frogs. The path of the ball indicated the area the tremor came from. Modern seismographs began their development in 1848.

There are literally millions of earthquakes that can be detected by a seismograph each year. Thousands are strong enough to be felt by people. The principle behind a traditional seismograph is rather simple. A weight is freely suspended from a support

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that is attached to bedrock. When waves from a distant earthquake reach the instrument, the inertia of the weight keeps it stationary, while the Earth and the support vibrate. The movement of the Earth in relation to the stationary weight is recorded on a rotating drum. It produces a seismogram that shows a continuous record of Earth movement. There are seismographic stations all over the world.

Management

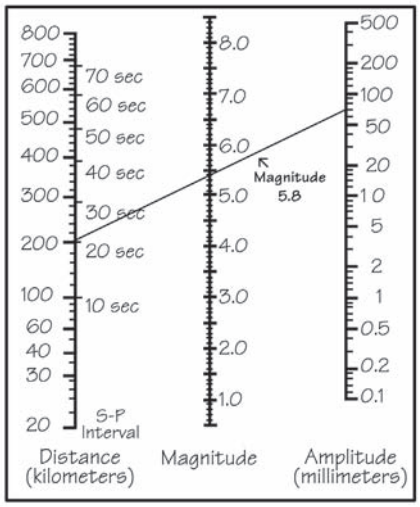
1. Emphasize to the students that the seismogram in this activity is highly simplified and that a real seismogram is far more complicated. Use the seismogram on the student page to help the students identify the following parts:
   - P waves and the P wave arrival time
   - S waves and the S wave arrival time
   - S-P interval (expressed in seconds)
   - S wave maximum amplitude (measured in mm)

   The P waves are the first to arrive at a seismographic station. The S waves will follow. The difference in time between the arrival of the P and S waves is called the S-P interval. The amplitude of the S wave is measured in mm and is read on the vertical axis of the seismogram. The maximum amplitude can be above or below the 0 line on the seismogram.
2. To locate an earthquake's epicenter, you need to have the seismogram readings from three sites. On each of the seismogram you will need to determine the S-P interval. The S-P interval will then be used to determine the distance the waves traveled from the origin of that station.
3. The epicenter for *Data Set One* is in the northwest corner of Wyoming (Yellowstone National Park) and the second epicenter is Charleston, South Carolina. Both of these sites are seismologically active areas.
4. The map scale should measure 7 mm equals 100 km. You may need to have students adjust their scale compass cards as a result of distortion that occurs when items are photocopied.

Procedure

Part One

1. Ask the *Key Question* and review the *Learning Goals*.
2. Distribute the first student page with the model seismogram. Direct the students to examine the model seismogram. Have students locate and identify the following parts:
   - P waves and the P wave arrival time
   - S waves and the S wave arrival time
   - S-P interval (expressed in seconds)
   - S wave maximum amplitude (measured in mm)
   - The scale intervals [The horizontal scale on these seismograms is 2 seconds and the vertical scale 10 mm.]
3. Tell the students to determine the P-wave arrival time, S-wave arrival time, S-P interval in seconds, and S-wave maximum amplitude for each of the two examples.
4. Show the students how to use the Richter Nomogram to determine the distance the earthquake has occurred from the seismograph. The students will need to first know the S-P interval. They will then use the left portion of the Richter Nomogram that lists distance and S-P interval. The students will follow the vertical column of the S-P interval up the Richter Nomogram until they reach the interval in seconds that matches the seismogram reading. They will then read the corresponding distance by reading horizontally across the column. This distance is called the epicentral distance. The Richter Nomogram is used to determine the distance each of these examples would have been from the epicenter of the earthquake. This distance is referred to as epicenter distance.
5. Instruct the students how to use the Richter Nomogram to estimate the magnitude of the earthquake. Direct them to plot the distance on the left column and the amplitude on the right column. Tell them to draw a line to connect the two points. The magnitude can be estimated by reading the point where the line crosses the magnitude scale in the middle. Use the Richter Nomogram to estimate the magnitude of the two sample earthquakes.

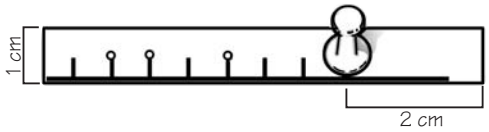


The Richter Nomogram

Part Two

1. Ask the *Key Question* and review the *Learning Goals*.
2. Distribute the maps and data sets. Determine the P wave arrival time, S wave arrival time, S-P interval in seconds, and S wave maximum amplitude for each of the seismograms.

3. Use the Richter Nomogram to determine the distance each station was from the earthquake's epicenter.
4. Tell the students to tape the maps onto the cardboard.
5. Have the students construct the two scale compass cards. The students will need to use a different scale compass card for each earthquake. The cards are constructed from a 3 by 5 index card. Direct the students to:
   - cut off two 1-cm strips from the three-inch dimension of the card;
   - place the factory cut edge of each strip along the scale of the map and trace the map scale onto it;
   - start marking the scale 2 cm from the end;
   - use the pushpin to place a hole on the middle of the first line (0 km);
   - determine the distance from each of the seismograms from *Data Set One*; and
   - use the pushpin to punch a small hole matching the three distances from the three seismograms on the scale compass card.
6. Direct the students to use the scale compass card to draw the three circles that go with the data set. Place the pushpin on each of the three different cities and draw a circle using that city's epicentral distance by placing a very sharp pencil in the corresponding hole. The earthquake's epicenter is located at the intersection of the three circles. The students will need to make a new scale compass card for the second data set.



7. Assist them, if necessary, in identifying the location of the earthquake's epicenter.
8. Tell the students to use the Richter Nomogram to estimate the magnitude of the earthquake.
9. Ask the students what they notice about the amplitude and location of the epicenter. [the larger the amplitude, the closer to the epicenter.]
10. Have the students examine the second set of seismograms. Have them predict which is the closest station, the middle station, and the furthest station from the epicenter. Then have them find the epicenter of this earthquake and estimate the magnitude.

Connecting Learning

1. What is the difference in a seismogram and a seismograph? [The seismogram is the chart of an earthquake. The seismograph is the instrument that makes the seismogram.]
2. Why is it necessary to use three stations when locating an earthquake's epicenter?
3. What do you notice about the maximum amplitude at each seismographic station and the location of the epicenter? [the larger the amplitude, the closer to the epicenter]
4. Why is it important to determine the scale before reading a graph or instrument?
5. In what part of the country do you think there are the most seismographic stations?
6. Would a fourth station reading be useful? [It depends on the location, a close station may give more information on the magnitude of the earthquake.]

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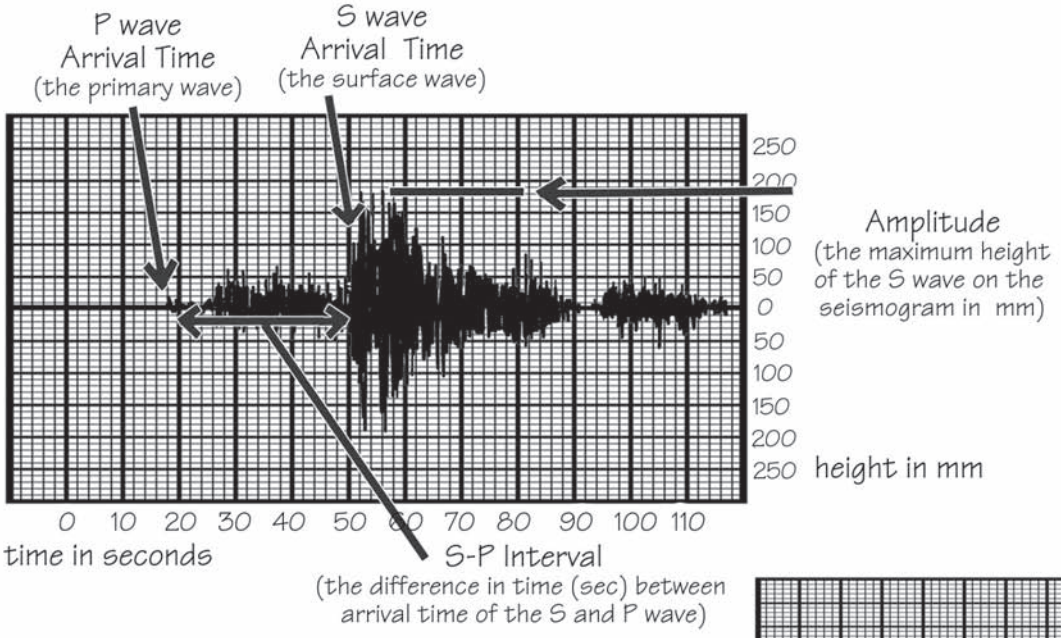
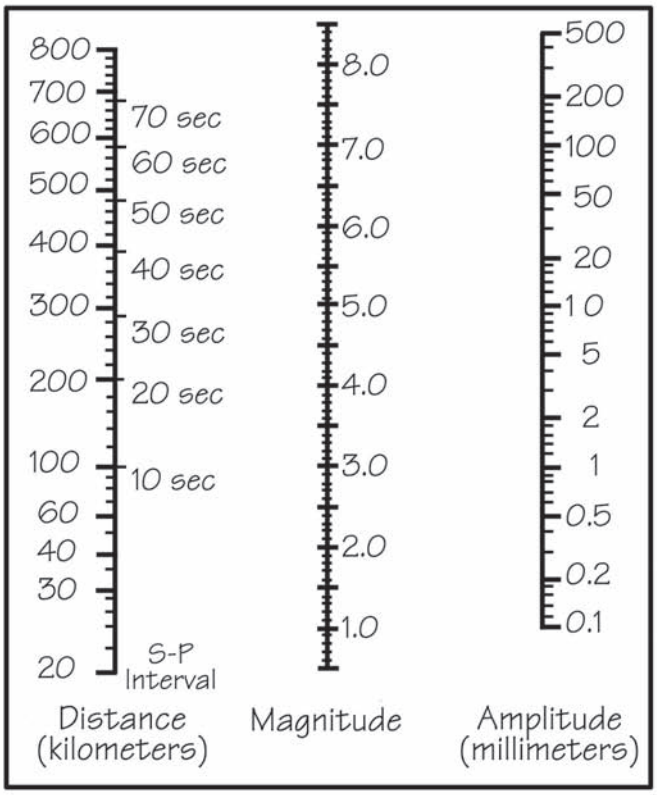
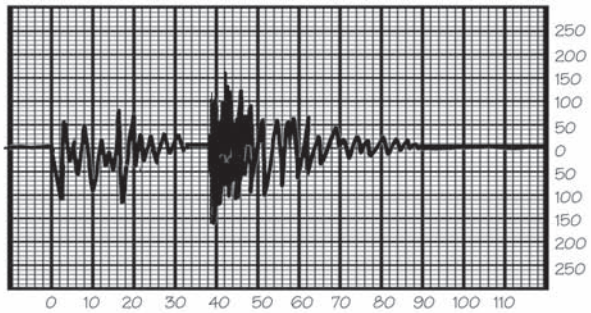
Quake Quest





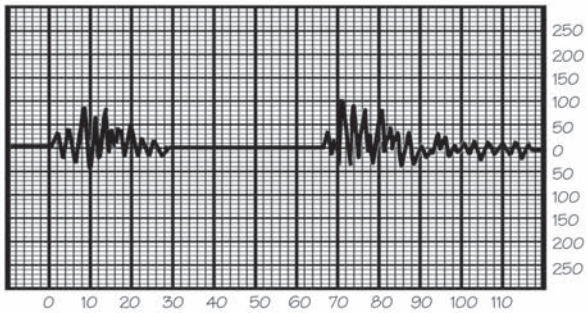
The Richter Nomogram



S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____



S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____

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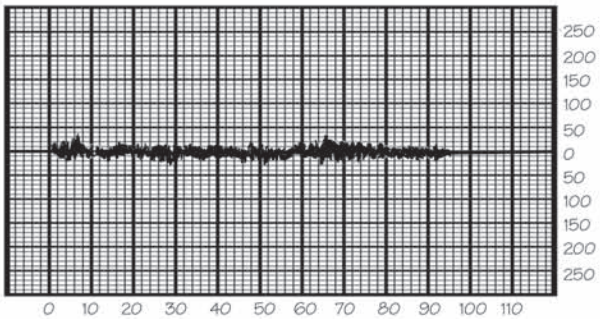
Quake Quest

DATA SET ONE

Cheyenne, WY

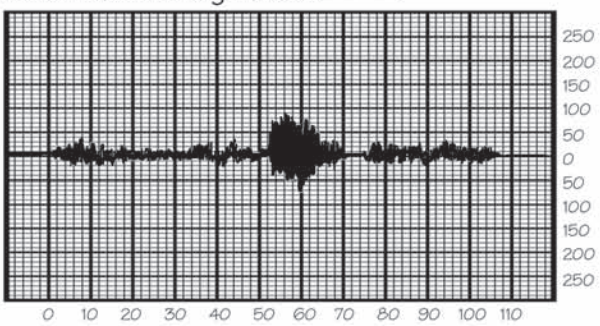


S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____

Salt Lake City, UT

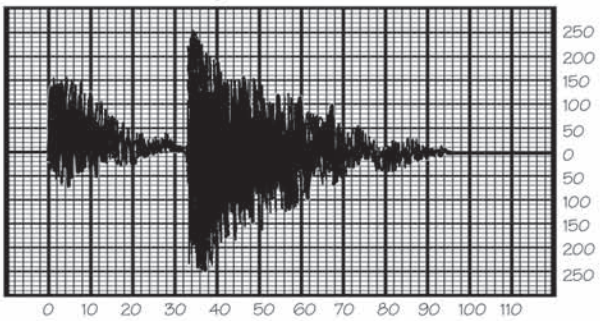


S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____

Helena, MT



S-P Interval_____sec Amplitude ____ mm

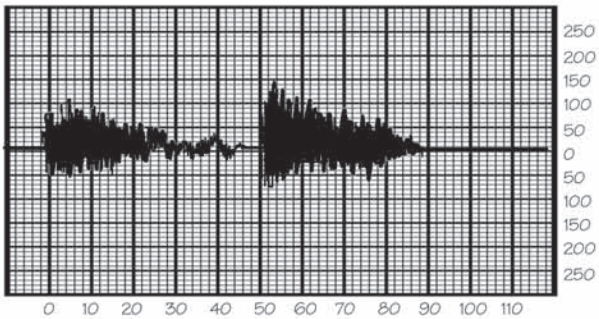
Epicentral Distance_____km

Estimated Magnitude_____

Where is this earthquake's epicenter?

DATA SET TWO

Atlanta, GA

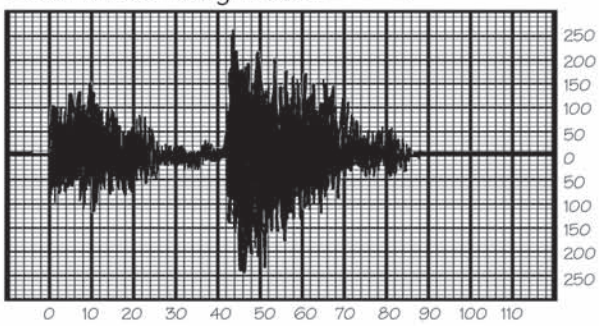


S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____

Raleigh, NC

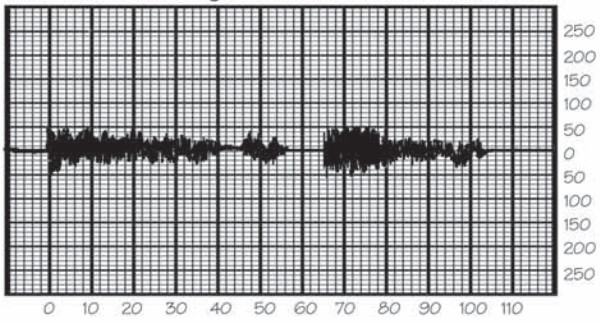


S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____

Tampa, FL



S-P Interval_____sec Amplitude ____ mm

Epicentral Distance_____km

Estimated Magnitude_____

Where is this earthquake's epicenter?

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Seattle
WA
Spokane
Portland
Eugene
OR
Helena
MT
Billings
ND
Bismarck
Fargo
Boise
ID
SD
Rapid City
Sioux Falls
WY
Cheyenne
NE
Omaha
Sacramento
Reno
NV
Salt Lake City
UT
San Francisco
Denver
Colorado Springs
CO
Topeka
CA
KS
Wichita
Las Vegas
Los Angeles
Santa Fe
Tulsa
AZ
Amarillo
OK
Albuquerque
Oklahoma City
San Diego
Phoenix
NM
Tucson
Dallas
El Paso
TX
San Antonio

Quake Quest

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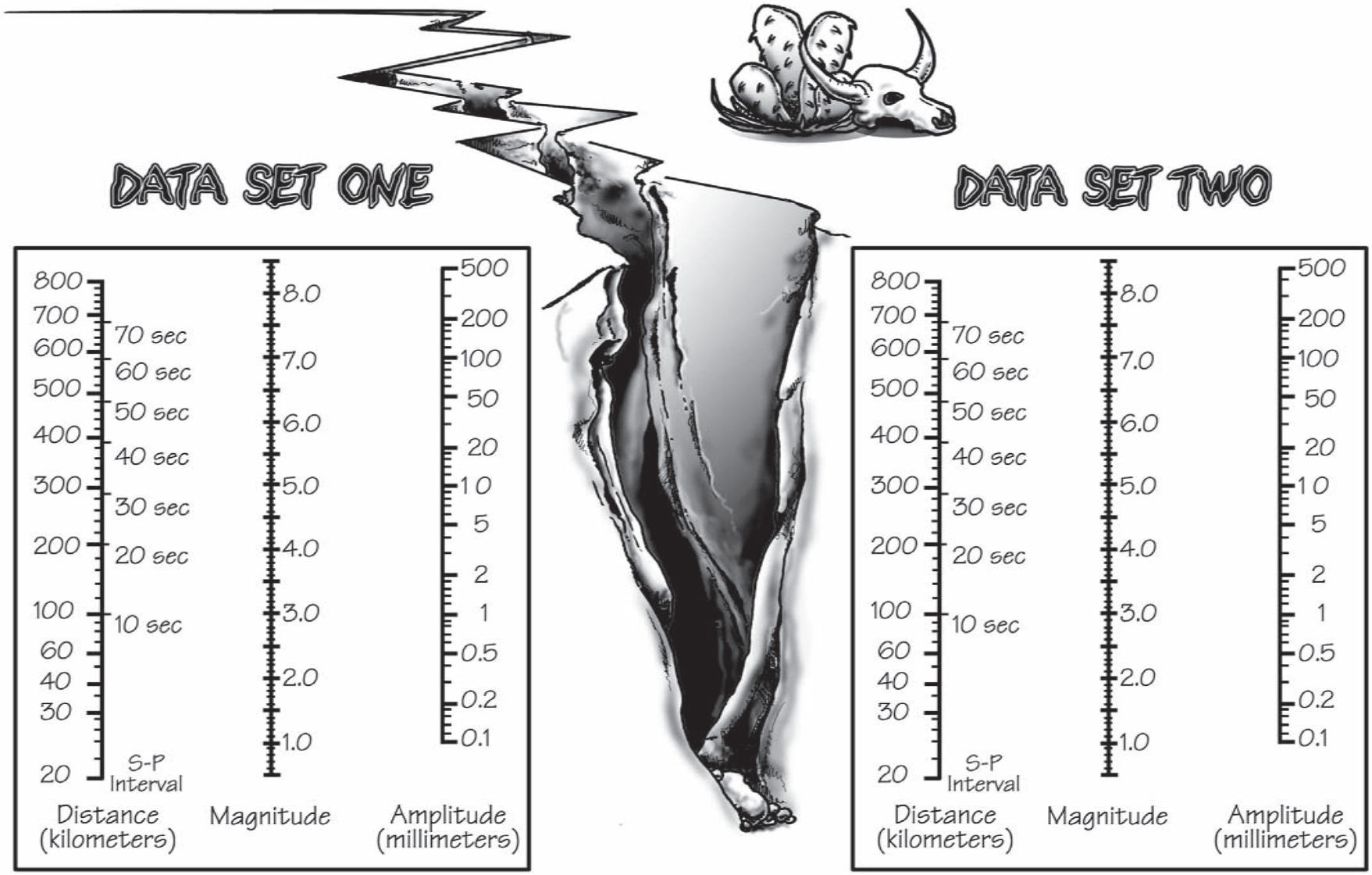
Quake Quest



The Richter Nomogram

The Richter Nomogram

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Tub Temps

Topic
Heating and cooling of soil versus water
Properties of matter

Key Question
How do the temperatures of soil and water compare over time?

Focus
Students will compare the rate with which soil and water gain and lose heat energy.

Guiding Documents
Project 2061 Benchmarks
- *The sun warms the land, air, and water.*
- *Some materials conduct heat much better than others. Poor conductors can reduce heat loss.*
- *Things change in steady, repetitive, or irregular ways — or sometimes in more than one way at the same time. Often the best way to tell which kinds of change are happening is to make a table or graph of measurements.*

NRC Standards
- *Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers.*
- *Earth materials are solid rocks and soil, water, and the gases of the atmosphere. The varied materials have different physical and chemical properties, which make them useful in different ways, for example, as building materials, as sources of fuel, or for growing the plants we use as food. Earth materials provide many of the resources that humans use.*

NCTM Standards
- *Make and use measurements in problems and everyday situations*
- *Construct, read, and interpret displays of data*

Math
Measurement
  time
  temperature
Whole number operations
Graph
  line

Science
Physical science
  properties of matter
  heat energy
Earth science
  meteorology

Integrated Processes
Observing
Predicting
Collecting and recording data
Comparing and contrasting
Controlling variables
Interpreting data
Relating

Materials
For the class:
  2 light-colored buckets or tubs
  3 thermometers
  stick, 1-1.5 meters long
  soil
  tool to scoop soil
  water
  crayons or colored pencils

For an optional approach using groups, see materials suggested in *Management 7*.

Background Information
Soil absorbs heat energy faster than water, but also releases it more quickly. Water warms and cools very slowly. A look at the properties of soil and water helps provide the explanation of why this happens.

1) Soil is opaque; water is transparent. The sun's rays pass through transparent materials more readily than opaque materials, distributing the heat energy to greater depths. Since sunlight can't pass through the rough, dark surface of soil, the heat energy is absorbed only at the surface. Have you ever dug into the sand on a hot beach and felt how cool it is underneath?
2) Water, because it is a liquid, moves easily. The water molecules help transport heat to different areas and depths (convection). Soil, a solid, is more stationary and the heat remains at the surface. The heat energy absorbed in land is transferred by contact (conduction).
3) Water has a greater capacity for heat. It takes more heat to raise the temperature of water than it takes to raise the temperature of the same amount of soil. Water is slow to take in heat but then equally stingy about releasing it. Water temperatures vary less over time than soil temperatures.

The different rates with which land and water absorb heat energy affect our weather. The Earth's land masses (soil) and oceans (water) release varying amounts of heat energy into the air above them. This creates air masses with different temperatures. Coastline cities

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which receive breezes off the ocean will likely have moderate temperatures because water gains and loses heat slowly. Inland cities will generally have greater temperature extremes because the soil will heat quickly during the day and cool rapidly as the sun goes down.

The purposes of this activity are to sharpen students' observation skills as they look at the properties of soil and water, to practice controlling variables as they measure time and temperatures, to produce a line graph which shows change over time, and to interpret the data they have collected. The results of this experience should be related to geography and weather when students are ready to make these connections.

Management

1. Plan to do this activity during a warm time of the year — late spring, summer, or early fall.
2. At least one hour before doing the activity, prepare the containers by filling one about two-thirds full of water and another about two-thirds full of soil. To achieve equal starting temperatures, add hot or cold water until the water temperature matches that of the soil.
3. Find three thermometers with matching readings. To measure air temperature, tape one thermometer to the top of the 1 to 1.5 meter stick. Air temperature should be taken in the shade over a grassy surface at about a height of 1.5 meters.
4. For the sun readings, put the thermometers in the soil and water just long enough for them to stabilize and be read. Then remove them. Otherwise the thermometers will be registering the sun's radiation along with the temperature of the soil or water.
5. Take an equal number of readings in the sun and the shade, not counting starting temperature. Plan for at least a two-hour block of time during the heat of the day.

	Time	Soil Temp.	Water Temp.
Start	12:30		
	12:45		
	1:00		
Sun	1:15		
	1:30		
	1:45		
	2:00		
Shade	2:15		
	2:30		

6. Always read thermometers at eye level and do not remove the bulb from the soil or water when reading.
7. To do this activity in small groups, transparent containers with a wide opening such as liter boxes or pint jars can be substituted for the buckets or tubs. Each group will need a set of the remaining materials listed.

Procedure

1. Place the two buckets, one with water and one with soil, in a place where students can gather and observe. Have them use their senses, particularly sight and touch, to describe each kind of matter.
2. Distribute the first activity page and have them record their descriptions.
3. Ask students to predict which will warm up faster, soil or water, or if they will warm up at the same speed. They should also comment on which material will cool down faster. Ask for reasons on which the students base their predictions, then have them write the predictions.
4. Discuss how often to take the temperatures (every 10, 15, 20, 25, or 30 minutes) and have students record the time interval.
5. Instruct students to place the thermometer bulb about the same distance under the water and soil each time. The temperature changes at different levels. A depth of three to four centimeters is recommended.
6. Take the class outside to a grassy spot where both sun and shade are available. Measure the air, soil, and water temperatures in the shade. Have students describe the weather — wind, clouds, air temperature, etc. — in the space provided. They should also record the time and starting temperatures of the soil and water. (Air temperature is not likely to match soil and water temperatures.) The use of Celsius measurements is encouraged. Record the temperature scale being used as ϒC (Celsius) or ϒF (Fahrenheit).
7. Remove the thermometers from the containers and place the soil and water in a grassy, sunny spot. Go indoors.
8. Return outside a few minutes before the next reading. Have students put one thermometer in each container so that the thermometer faces away from the sun. After a few minutes, when the thermometers have stabilized, direct students to record the soil and water temperatures.
9. Remove the two thermometers and repeat the temperature readings at regular intervals throughout the afternoon. After taking several sun readings, move the containers into the shade and continue readings at the same time intervals. For shade readings, the thermometers may be left in the containers.
10. Ask students how to find the temperature range of soil. [Find the highest and lowest soil temperatures and compute the difference.] Repeat for water and record on the activity page.

(Please see TEMPS, page 29)

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11. Distribute the line graph. Have students label the vertical axis (temperatures), the horizontal axis (times), and give the graph a title. Discuss how to determine the temperature range and increments to be used.
12. Instruct students to complete the key and plot the data using two colors, one for soil and another for water.
13. Discuss the results and have students write what they have discovered.

Discussion

1. How would you describe the soil? [rough, dark, dull, solid, opaque, etc.] How would you describe the water? [smooth, shiny, transparent, liquid, etc.]
2. What variables did we control? [time intervals, depth thermometer was placed, how long thermometer was in place before reading]
3. How much did the soil's temperature change? (Find the temperature range: highest minus lowest temperature) How much did the water's temperature change?
4. Look at your graph. What patterns do you notice? [Examples: The temperature climbs sharply at first and then slows. It also drops sharply when first put into the shade. The soil temperature got warmer than the water temperature. *The Big Idea*: Water heats and cools more slowly than soil.]
5. What do you think might happen to the temperature of the air right above the soil? [Heat energy released from the soil would make air temperatures heat up quickly in the sun and cool down quickly in the shade.] What do you think might happen to the temperature of the air right above the water? [The air temperature wouldn't change as much as it did above the soil.] See *Extensions 3*.
6. Why don't you go swimming the first warm day of spring? [You will want to wait several days or weeks since it takes time for the water to absorb enough heat to make swimming a comfortable experience.]

Extensions

1. Measure and graph air temperatures along with soil and water temperatures at each time interval.
2. Design an investigation to compare the temperatures of soil and water at different depths.
3. Compare air temperatures 1 or 2 cm above soil and water over time.

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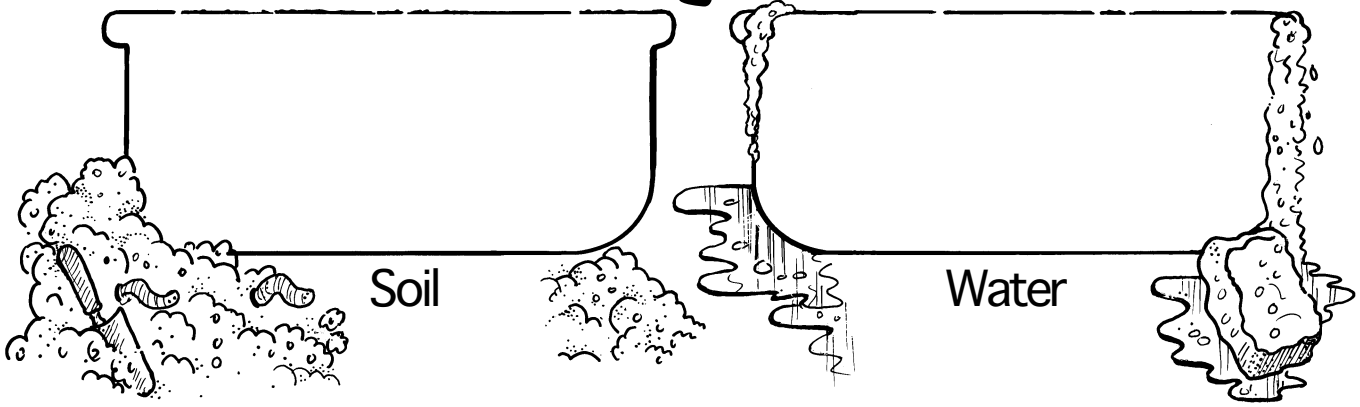
Tub Temps

Observe and describe.



How do the temperatures of soil and water compare over time?

Temperature scale: ♈ _____

Prediction:

Weather:

Time interval:
Thermometer depth:

	Time	Soil Temp.	Water Temp.
Start			
Sun			
Shade			

Soil Temperature Range

Water Temperature Range

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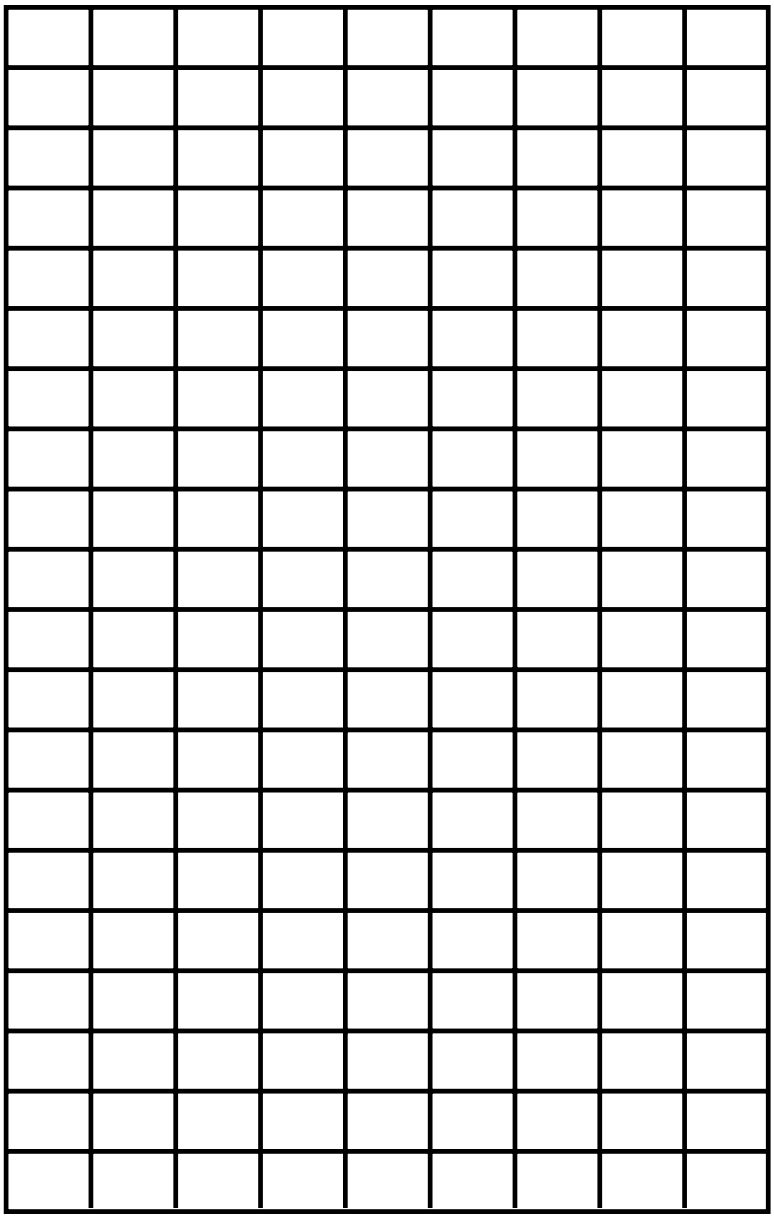
Tub Temps

Line Graph

What did you discover?



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ON LOCATION

Topic
Temperature: location variables

Key Question
How does location affect temperature?

Focus
Students will explore how temperatures are influenced by variables such as exposure to the sun, kind of surface, and height above the surface. This information will be linked to the standards used by meteorologists to take temperatures.

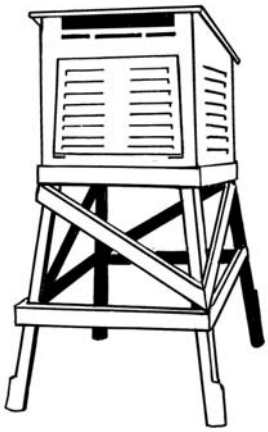
Guiding Documents
Project 2061 Benchmarks
- *Measuring instruments can be used to gather accurate information for making scientific comparisons of objects and events and for designing and constructing things that will work properly.*
- *Some materials conduct heat much better than others. Poor conductors can reduce heat loss.*

NRC Standards
- *The sun provides the light and heat necessary to maintain the temperature of the earth.*
- *Employ simple equipment and tools to gather data and extend the senses.*

*NCTM Standards 2000**
- *Select and apply appropriate standard units and tools to measure length, area, volume, weight, time, temperature, and the size of angles*
- *Collect data using observations, surveys, and experiments*
- *Represent data using tables and graphs such as line plots, bar graphs, and line graphs*

Math
Measurement
  temperature
  length
Ordering
Graphing
  bar

Science
Earth science
  meteorology
Physical science
  heat energy



Stevenson screen

Integrated Processes
Observing
Predicting
Controlling variables
Collecting and recording data
Comparing and contrasting
Interpreting data

Materials
Thermometers
Meter sticks for thermometers
Tape

Background Information

Temperature at a particular location and time is affected by several variables, among them exposure to the sun, the kind of surface, and the distance from the ground or structures. These variables can cause a relatively small area, such as a schoolyard (*Playground Fever)*, to have a range of temperatures rather than one uniform temperature. To measure the temperature of the *air*, which is what is reported in weather data, budding meteorologists need to understand the effects of these variables and how to control them when positioning the thermometer.

Sun exposure

Two friends visit outdoors on a cool day. After the goose bumps set in, they move to a spot in the sun and feel warmer. Is the temperature of the air warmer in that spot? Not necessarily. It is the direct radiation from the sun that warms them.

A thermometer exposed directly to the sun measures more than just the air temperature; it receives and registers the sun's radiant energy as well. And, the fewer the clouds and the more direct the angle of the sun's rays, the greater the amount of radiant energy that reaches Earth. To avoid measuring radiant energy, the thermometer should be shielded from the sun with objects such as a piece of paper, your body, a tree, or protective housing.

National Weather Service meteorologists place the thermometer in a Stevenson screen, a white, wooden, ventilated box with the instruments and door facing north. This box shields the thermometer from direct sun but allows breezes to flow through it. The white paint reflects heat energy better than darker colors. Wood is used because it is a poor conductor of heat energy. The instruments face north because that direction receives the least direct sunlight in the Northern Hemisphere. In the Southern Hemisphere, a southern orientation receives the least direct sunlight.

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Kind of surface

On a hot summer day, would a barefoot person feel more comfortable walking across an asphalt road or grass in the yard? Most of us have experienced the burning sensation of the scorching asphalt and would much prefer the coolness of grass.

On average, about half of the solar energy reaching Earth is absorbed while the other half is reflected back into space. How much is absorbed depends on the composition and color of the surface. Some materials, like asphalt, are better conductors than others. Then, too, dark colors absorb more heat energy than light colors.

The table[1] shows the typical amount of solar radiation reflected (albedo) by various surfaces. What is not reflected is absorbed or transmitted. So new snow is absorbing only about 10% of the radiation whereas asphalt is absorbing more than 90%.

Surface	**Albedo**
New snow	90%
Old snow	50%
Average cloud cover	50%
Light sand	40%
Light soil	25%
Concrete	25%
Green crops	20%
Green forests	15%
Dark soil	10%
Asphalt	8%
Water	8%[2]

Meterologists prefer to measure air temperature above a grassy surface. In the absence of grass, level ground typical of the surrounding area is chosen, though close proximity to paved or concrete surfaces should be avoided.

Distance from ground or structures

Matter that absorbs heat energy also emits heat energy. If a thermometer is placed on or very close to a surface, whether the ground or a building, heat energy from that surface will be conducted to the thermometer; it will register more than just the air temperature. Temperatures on sunny days are usually warmer close to the ground; at night, however, the ground temperature may be cooler than the air temperature since land loses heat quickly. So that heat energy emitted from the surface is not reflected in air temperature readings, the Stevenson screen is positioned 1.5 meters (about 5 feet) above the ground and away from structures.

1. Eagleman, Joe E. *Meteorology: The Atmosphere in Action.* Wadsworth Publishing Company. Belmont, CA. 1985.
2. The albedo for water varies greatly with the angle of the sun's rays. Near sunset, when the rays are very indirect, most of the radiation is reflected.

Management

1. To make valid comparisons, thermometers with matching readings are preferred. However, differing thermometers may be made equivalent by computation. Choose a baseline thermometer and determine by how much the others differ. Tape the amount to be added or subtracted (+1, -2, etc.) to these thermometers.
2. For valid measurements, make sure the thermometer is shaded. For preciseness, identify the scale and scale increments, wait for the thermometer liquid to stop moving, bring the eyes perpendicular to the scale, and read carefully. (See the activity, *A Matter of Degrees.)*
3. Tape the thermometers to meter sticks. They provide a built-in measure and make it easier for students to keep their hands away from the thermometer bulbs, which can be affected by body heat.

4. For optimum temperature contrasts, schedule this investigation when the most radiant heat reaches the Earth, namely when the sun's rays are more direct (hours near solar noon), the days are longer (late spring, summer, or early fall), and there are few or no clouds in the sky.
5. There are several options for implementing this activity.

> *Open-ended:* Students ready for more independent work should follow up their hypotheses from *Playground Fever* by designing, on their own paper, a scientific test for one of the variables (sun exposure, surface, height, etc.) The *Key Question* can also be given: "How does location affect temperature?"
>
> *Guided planning:* Ask the *Key Question:* "How does location affect temperature?" Have students identify variables they want to explore, based on the *Playground Fever* investigation. On a transparency or chart paper, list questions such as these to help students plan on their own paper:
>
> What variable are you testing?
> What kinds of locations does this include?
> How are you going to control other variables?
> When and how often will temperature readings be taken?
> How will the results be recorded?
> What did you discover?
>
> *More structured:* Choose *Option A* in which students focus on variables of their own choosing, one at a time, or *Option B* in which students briefly test three specific variables.

6. If students are doing more in-depth work *(Option A),* plan on testing one variable each day. *Option B* may require one day for testing and another for examining data and writing conclusions.
7. For *Option B,* one page will be needed for each variable tested.

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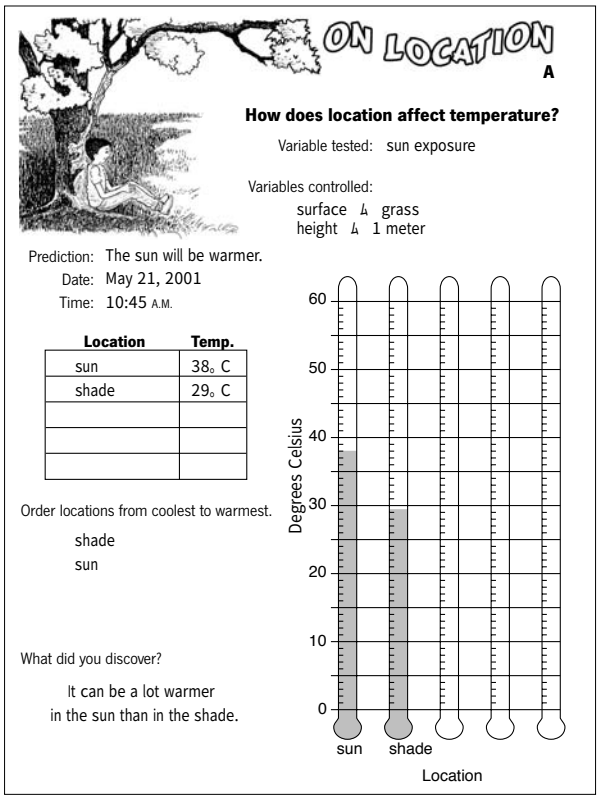
Procedure

Option A

1. Ask, "Does it make a difference where we put the thermometer to take the air temperature outdoors?" (Encourage responses.) "We are going to test how location affects temperature. What kind of variables do you think we might test?" (If at all possible, base the investigation on their responses but somewhere in the mix *sun exposure* (sun, shade), *surfaces* (grass, concrete, sand, asphalt, dirt, etc.), and *height* (0 meters, 1 meter) should be addressed. Proximity to buildings (another distance variable), color, and the presence of water are other possibilities.)
2. Give students the *Option A* activity page. Have them record the variable to be tested and those which will be controlled. Students should also identify **how** they will be controlled.

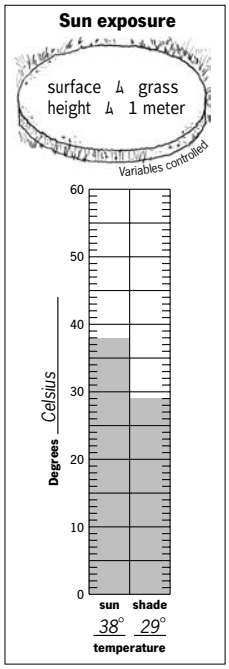


3. Have students predict which location will be warmest.
4. Take the class outside to the appropriate locations. Have students position the thermometers, wait for them to equilibrate, read the temperatures, and record them. Groups of students can each take their own measurements.
5. Back inside, instruct students to rank the locations based on actual data, complete the bar graph, and write their conclusions. Share data between groups.
6. Repeat steps 2-5 for each variable, using a separate page for each. Students should explore a minimum of three variables—sun exposure, surface, and height—in order to understand the standards used by meteorologists for taking air temperature.

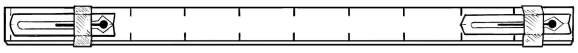
Journal Prompt: What combination of locations would best register just air temperature? Why?

Option B

1. Ask the *Key Question:* "How does location affect temperature?" (Students should reflect on their experience in *Playground Fever*, identifying some of the possible variables. Guide the discussion so that it includes *sun exposure* (sun, shade), *surface* (grass, concrete, sand, asphalt, dirt, etc.), and *height* (0 meters, 1 meter).
2. Distribute the *Option B* page and draw attention to the first variable to be tested: sun exposure. Discuss together over what surface and at what height to conduct the test. A one-meter height is strongly encouraged to counter any effects from the surface.



3. Review how to take precise measurements (see *Management 2)*. Assign and have several groups of students take sun/shade measurements, depending on the number of thermometers available.
4. Together, plan and record the surface locations to be tested, depending on what is available in your schoolyard. Decide the controlling height (on or close to the ground) and sun exposure (sun maximizes the results, a desirable condition).
5. After repositioning the thermometers on the meter sticks, have student groups measure the temperatures and order the surfaces from cool to warm.
6. Discuss, as a class, the variables to control when testing height. Decide the controlling surface (the surface can vary from group to group) and sun exposure. Again, the sun will yield more variation than shade.
7. Instruct students to tape two thermometers in identical positions, but at opposite ends of the same meter stick, as both readings can be taken at the same time.



8. After the height measurements are gathered and recorded, have students examine the data.

Journal prompt: What combination of locations would best register just air temperature? Why?

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Discussion

1. What surprised you about the results?
2. How does your group's data compare to others?
3. What combination of variables would give the coolest reading? …the warmest reading?
4. What standards do you think meteorologists *might* use to take the air temperature? Why? (Encourage students to voice their opinions, but do not expect them to fully determine the standards from their data. At some point, introduce the standards mentioned in *Background Information*.)
5. An announcer of a major championship tennis match, such as the French or U.S. Open, says the temperature is 92°F but on the court it is 101°F. What do you think makes it hotter on the tennis court? [exposure to the sun, the clay or concrete surface, the enclosed space of center court which blocks breezes, the combined heat radiating from all the spectators, etc.]

Extensions

1. Introduce the time variable by doing sun/shade temperature measurements every hour or two throughout the school day. How does the difference between the sun and shade measurements change? [Unless clouds interfere, the difference should increase from morning (more indirect rays) to solar noon (most direct rays) and then decrease toward sunset.]

Time	Location	Temp.
	sun	
	shade	
	sun	
	shade	
	sun	
	shade	

2. To explore how different colors absorb heat energy, do the activity *Hot Pockets*, found in *AIMS*®, Volume XIII, Number 2.

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Connections

The sun is the source of the Earth's heat energy, but all locations do not heat equally. It is this unequal heating that causes weather. We have found that shady spots are cooler than those exposed to the sun's radiation. Some surfaces, such as asphalt, absorb and radiate more heat energy and, through conduction, raise the temperature of the air close to that surface.

The heat energy investigation just completed relates to the scientific process, too; when meteorologists take measurements, they isolate one variable. To measure the temperature of the air alone, the thermometer is shielded from sun exposure and the effects of varying surfaces by placing it in the shade or a protected, ventilated box 1.5 meters above a grassy surface.

This knowledge of variables will be applied in the next activity, *Temperature Tally*, as we choose an appropriate location for an informal weather station.

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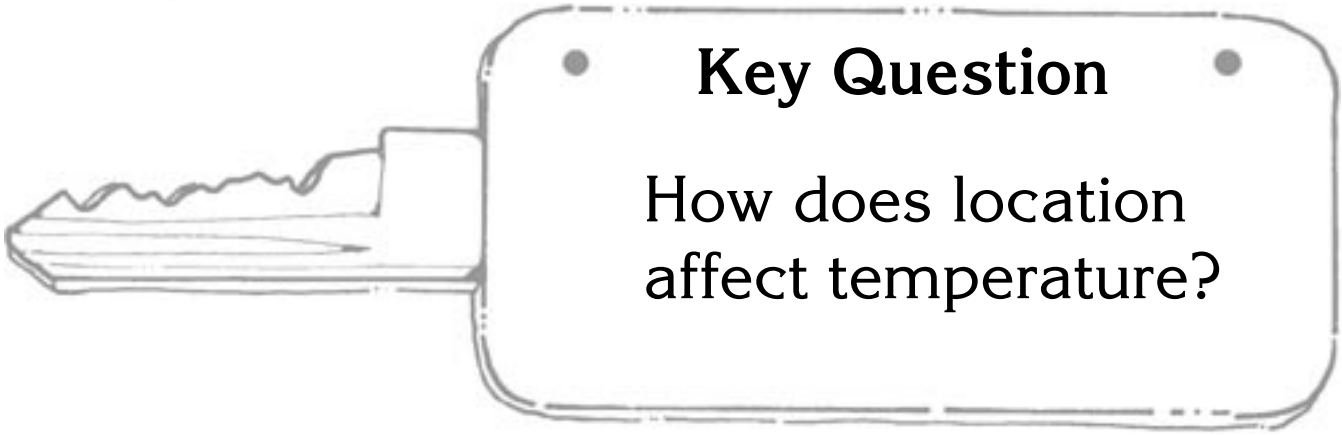
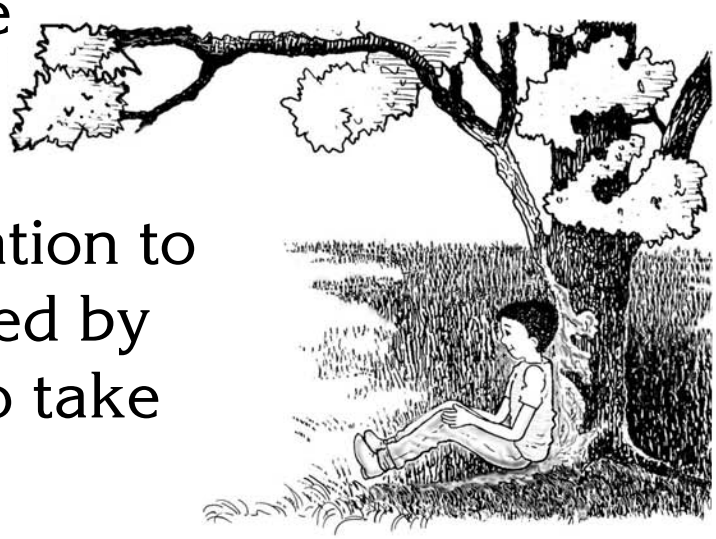


Learning Goals

Students will:

- explore how temperatures are influenced by variables such as exposure to the sun, kind of surface, and height above the surface; and



- link their information to the standards used by meteorologists to take temperatures.

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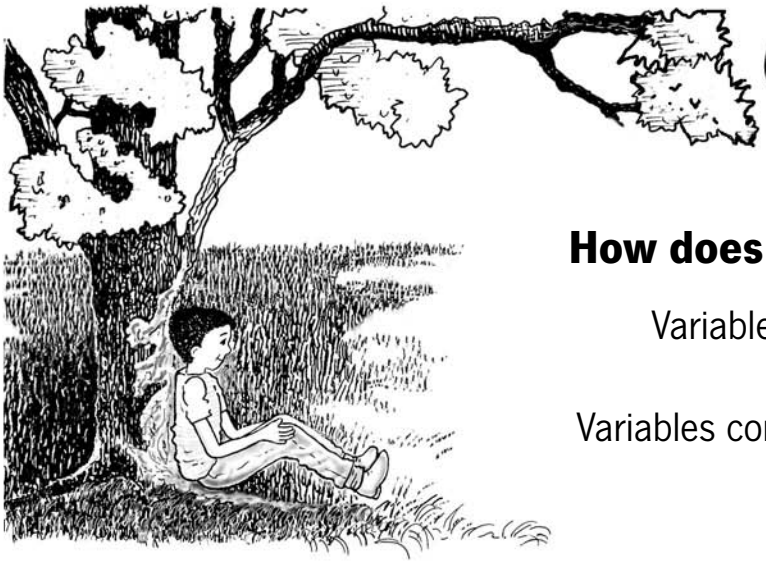


ON LOCATION

A

How does location affect temperature?

Variable tested:

Variables controlled:

Prediction:

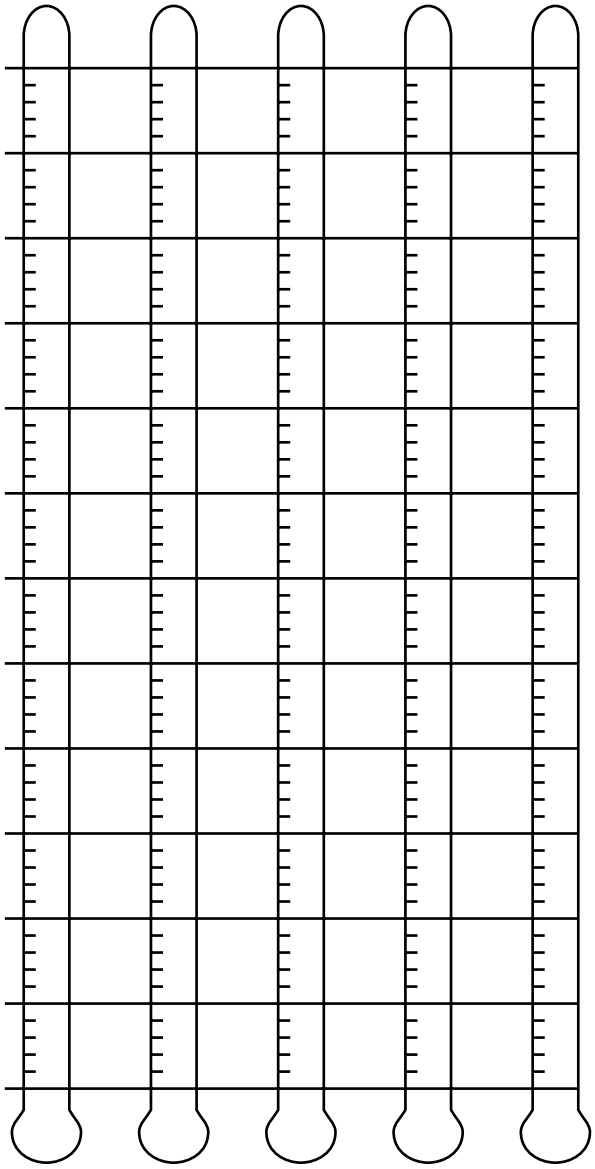
Date:

Time:

Location	Temp.

Order locations from coolest to warmest.

What did you discover?



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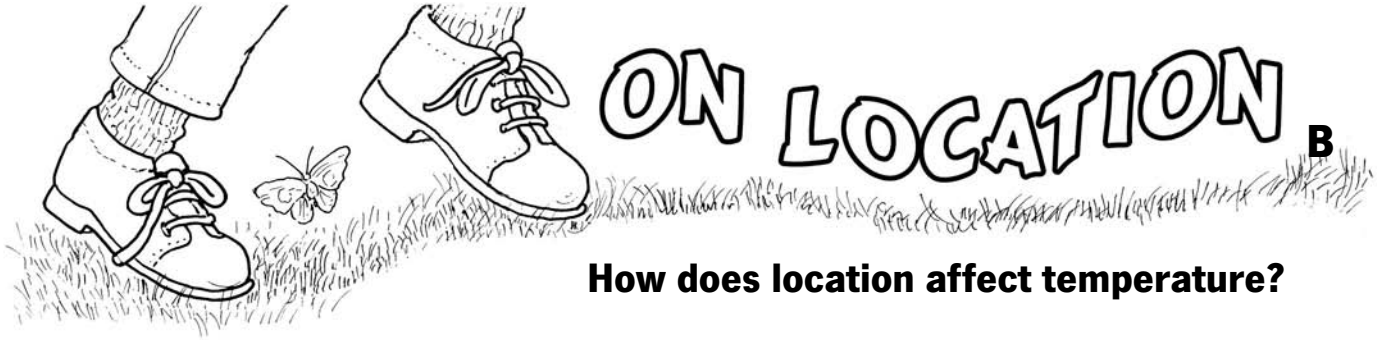
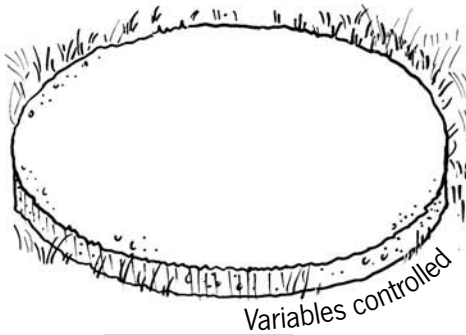
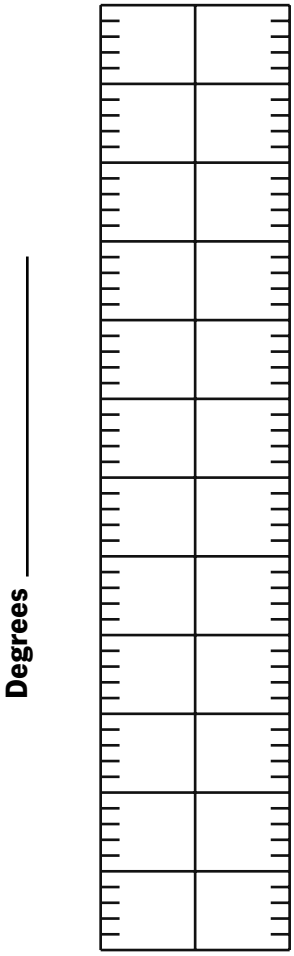


ON LOCATION B

How does location affect temperature?

Sun exposure

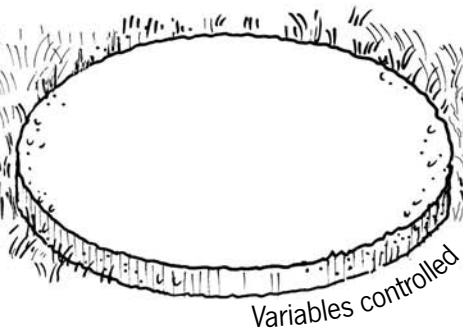




_____ _____

temperature

Surface



Location	Temp.
concrete	
grass	

Order from cool to warm.

_____

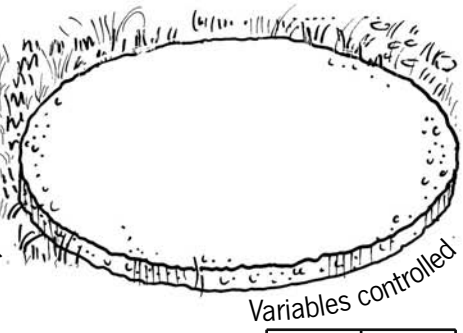
_____

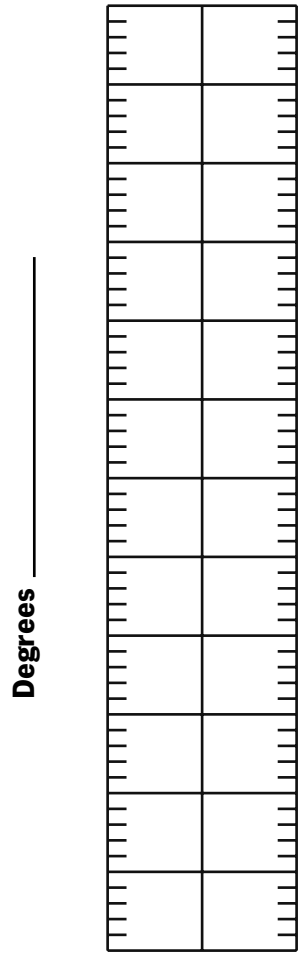
_____

_____

_____

Height





_____ _____

temperature

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Connecting Learning

1. What surprised you about the results?

2. How does your group's data compare to others?

3. What combination of variables would give the coolest reading? …the warmest reading?

4. What standards do you think meteorologists *might* use to take the air temperature? Why?

5. An announcer of a major championship tennis match, such as the French or U.S. Open, says the temperature is 92°F but on the court it is 101°F. What do you think makes it hotter on the tennis court?

6. What are you wondering now?

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Heat Bands

Topic
Temperature patterns: isotherms

Key Questions
How can a map be turned into a temperature graph?
How does geographical location affect temperature?

Focus
Students will interpret an isotherm map based on increments of ten, noticing temperature patterns related to latitude. For those who are ready, opportunity is given to learn how to draw isotherms using data they gather.

Guiding Documents
Project 2061 Benchmarks
- *Graphical display of numbers may make it possible to spot patterns that are not otherwise obvious, such as comparative size and trends.*
- *Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.*

NRC Standard
- *Weather changes from day to day and over the seasons. Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation.*

*NCTM Standards 2000**
- *Represent data using tables and graphs such as line plots, bar graphs, and line graphs*
- *Describe the shape and important features of a set of data and compare related data sets, with an emphasis on how the data are distributed*

National Geography Standards
- *Show spatial information on geographic representations*
- *Obtain information on the characteristics of places (e.g., climate, elevation, and population density) by interpreting maps*

Math
Number sense
  ranges
Spatial sense
Graphing

Science
Earth science
  meteorology

Social Science
Geography
  United States (adaptable to other countries)

Integrated Processes
Observing
Collecting and recording data
Comparing and contrasting
Interpreting data
Relating

Materials
Crayons or colored pencils (see *Management 1)*
Temperature data from newspaper
Globe

Background Information
On television weather reports, in the newspaper, and online, students have seen weather maps banded by isotherms, lines of equal temperature. This activity focuses first on interpreting an isotherm map, then on the more challenging skill of gathering data and drawing isotherms.

Isolines is the general name for lines of equal value. Specific names are given for specialized data: isotherms (temperature), isobars (barometric pressure), isohumes (humidity), and so on.

An isotherm map is actually a specialized kind of graph, a graph being "a pictorial device used to display numerical relationships." Microclimates, such as the classroom, can be mapped with 1-degree isotherms. More commonly, isotherm maps with 10-degree increments represent the temperatures of large land masses, whether whole continents such as Europe, Africa, and South America or large countries such as Canada, Australia, and the United States.

Isotherm maps show the relationship of geographical locations—latitude, proximity to large bodies of water or land—with temperature. With further research, location factors such as elevation, mountains, and other physical features can deepen the connections.

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Management

1. Choose a color scheme for the key. Consider coordinating it to your local paper or the *USA Today*® isotherm key. Find an assortment of crayons or colored pencils that matches the key. Several shades of blues, greens, and oranges are often necessary.

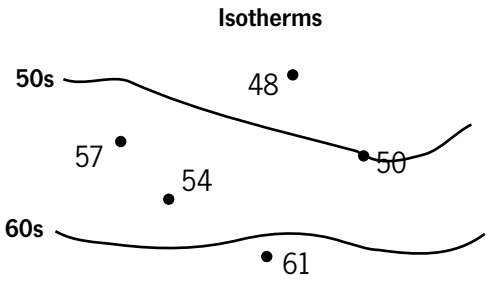
below zero	0s	10s	20s	30s	40s	50s	60s	70s	80s	90s	100s

2. Because U.S. temperatures are presently reported in Fahrenheit, use that scale.
3. Since interpreting and drawing isotherms are likely a new experience, working with a partner may help students gain confidence. The whole class will be involved in gathering and sharing data with each other in *Part Two*.
4. Collect several copies of the weather section of the local newspaper or *USA Today*® for two consecutive days. They do not have to be the current issues but should be recent ones.
5. Emphasis is on drawing an isotherm *between* two temperatures rather than being concerned that it should be closer to one than the other. If, for example, there are temperatures of 58 and 65, the 60s isotherm need not be drawn closer to 58 than to 65. In fact, more data would be needed to fine-tune the line positions. The focus is instead on the general picture. Drawings will vary somewhat from person to person.
6. Be aware of several guidelines when drawing isotherms:
   a. Isotherms should be drawn in relation to city points, not to the position of the city name or the temperature number.
   b. The lines should be drawn *through* any city point with a "tens" temperature such as 40 or 50.
   c. Isotherms must be consecutive, either up or down one from its neighbor. If one city is in the 50s and a neighboring city is in the 70s, a 60s isotherm must be inserted between them.
   d. Isotherms should begin and end at the map's boundary lines.
   e. There can be more than one of the same isotherm on a given map.
7. This activity can easily be adapted to other countries by substituting a map of the continent or country (if it has at least three temperature bands) for the final page in *Part Two*.

Procedure

Part One: Interpreting isotherms

1. Hold up a newspaper with an isotherm map. Ask, "Does anyone recognize this map? What does it show? Where else have you seen one?" [television weather report, weather website, etc.] Explain that the colored bands represent a 10-degree temperature range. Point to one of the bands, as an example, and tell the class all the cities in this band had temperatures in the ____ (50s or whatever is appropriate). The lines separating the bands are lines of equal temperature called isotherms. (Point to one line.) Along this line, the temperatures are 50 degrees. (Point to another line.) This is the 60-degree isotherm. So temperatures between 50 and 60 are in this band.



2. Give students the first map, with the isotherms drawn. Guide the coloring of the isotherm key according to the color scheme you have chosen (see *Management 1)*.
3. Model how to color each city point, using the isotherm key as a guide. This procedure helps students better see how the bands were constructed and prepares them for drawing their own maps. Then have them fill in the bands completely with color.
4. Study the map together. Use the discussion questions to guide interpretation.
5. Follow up by having student groups examine two consecutive newspaper temperature maps, noticing repeated patterns and changes. The same discussion questions can be used.

Part Two: Drawing isotherms (for those students who are ready)

1. Distribute the page with two practice maps and instruct students to color the key and city points of the upper map as they did in *Part One*.
2. Encourage students to look at places where the city colors change and draw a line between those areas, from map boundary to map boundary, until all the temperature areas have been defined. Circulate to provide assistance as needed.
3. Have students color the city points on the lower map, an island. Newburg (74) and Greenfield (92) have no 80s temperature between them so guide students through the drawing of both an 80s and a 90s isotherm. They should notice there are two

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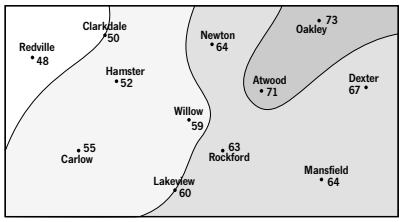
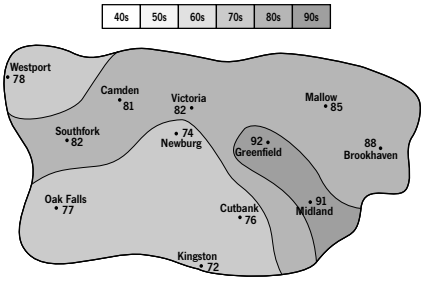
80s isotherms or, in another way of looking at it, two bands of 70s.





4. Bring in newspaper temperature data, which will be the previous day's highs, and instruct students to write the temperatures by each city on the United States map provided or a continent or country map of your choice.
5. Have students color-code the city points, draw the isotherms, and color the temperature bands.
6. Discuss the patterns.

Discussion

Part One

1. What is the range of temperatures on this map? [40s to 90s]
2. Trace (or point to) the 60s isotherm with your finger. [second isotherm from the top]
3. Name some other cities in the same temperature band as ours. What do the locations of these cities have in common? [roughly similar latitudes]
4. Which temperature band covers the most area? …the least area?
5. Which part of the country is warmest? …coolest? [Warmer locations—the lower latitudes—are generally closer to the Equator which receives the sun's most direct rays. The higher latitudes, further from the Equator, tend to be cooler; the sun's rays are more indirect. (Use a globe to help students see the relationship.)]
6. What other temperature patterns do you notice? [There is a hot spot in southern Arizona and California. There is a north-south band of cooler temperatures along the West Coast, but it is warmer inland in California. The East Coast does not have a similar north-south cool temperature band. (Recognition of patterns is sufficient. The "why" requires more advanced knowledge of global wind patterns and the physical geography of the West and East Coasts. Students would also need to transfer learning from the *Tub Temps* investigation to national geography, a task more developmentally appropriate to the middle-school level.)]

Part Two

1. What was the easiest part about drawing this map? What was the most difficult?
2. What patterns do you notice on this map?
3. How does the map you drew compare to the one in the newspaper? (Students should have a feeling of accomplishment as they recognize similar patterns. Differences will arise because the newspaper is most likely using predicted rather than actual data and because its data are more extensive. To compare like data, yesterday's highs mapped by students would correspond to the newspaper forecast map from the day before yesterday.)

Extension

Save several newspaper temperature maps or student-drawn maps from different seasons. Have students compare the maps from two seasons, noting what has changed (temperature range) and what is similar (latitude patterns).

Curriculum Correlation

Technology

Have students investigate websites for isotherm maps of current weather conditions for their location and elsewhere in the world. See *Weather Websites* at the back of this book for suggestions.

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Connections

We have found that, at a particular location such as a school site, temperature varies. Isotherm maps show, on a larger scale, that the Earth heats unequally. Geographical location affects temperature. Latitudes closer to the Equator are warmer because they receive more of the sun's direct rays. This could lead to further study of the relationship between the sun and the Earth over the course of the year, why we have seasons.

In the meantime, it is time to assess what students have learned about the bigger picture of how location influences temperature.

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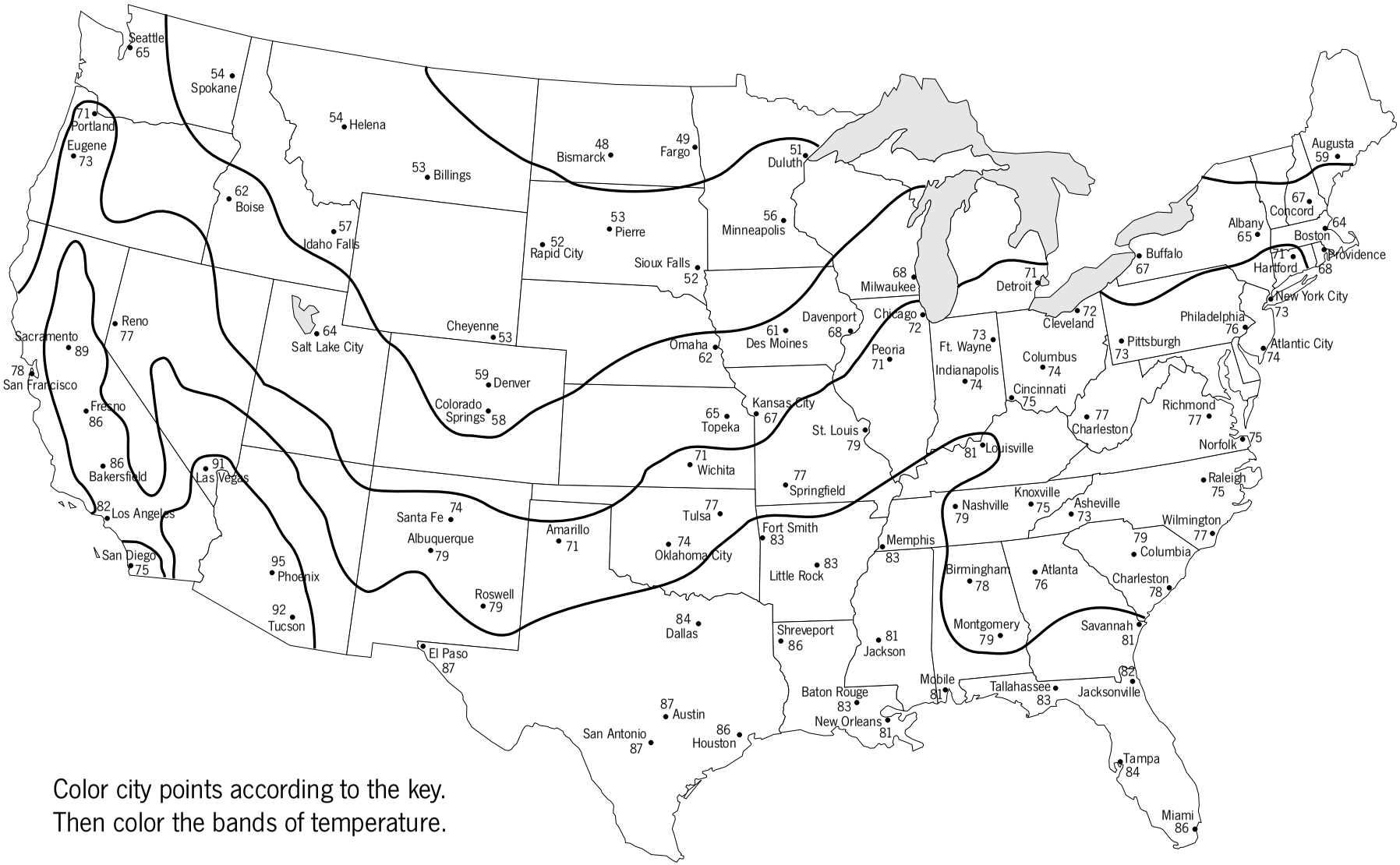
Heat Bands



Color city points according to the key.
Then color the bands of temperature.

40s	50s	60s	70s	80s	90s

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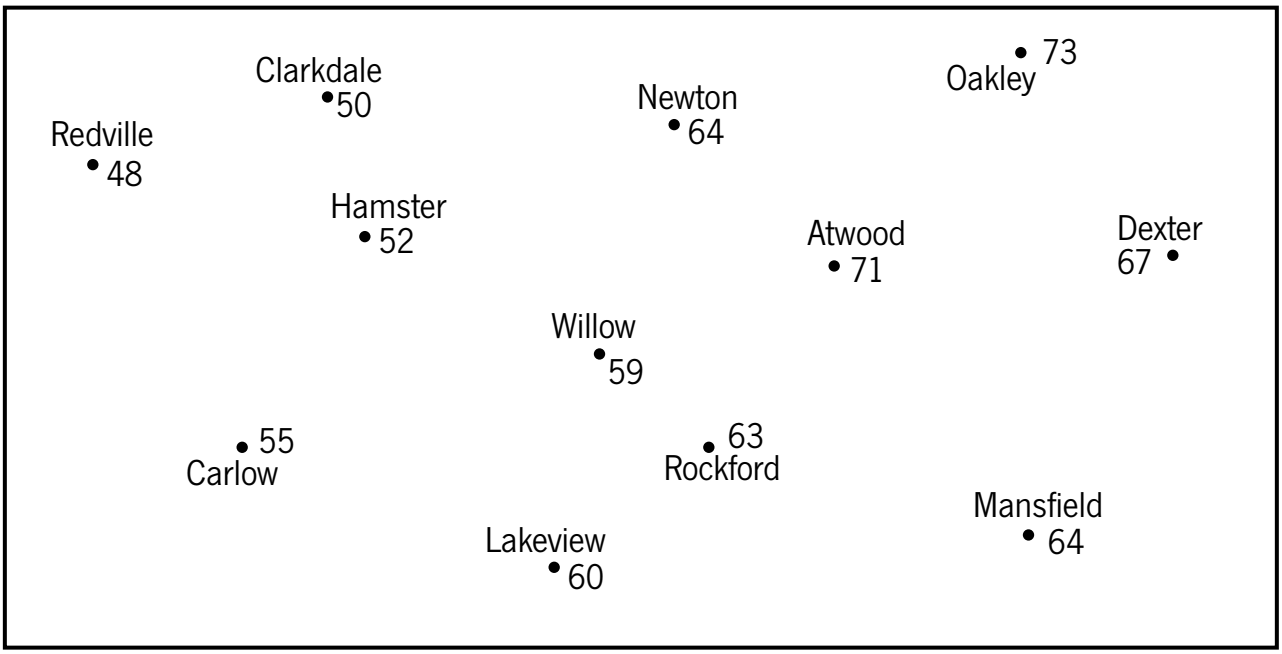
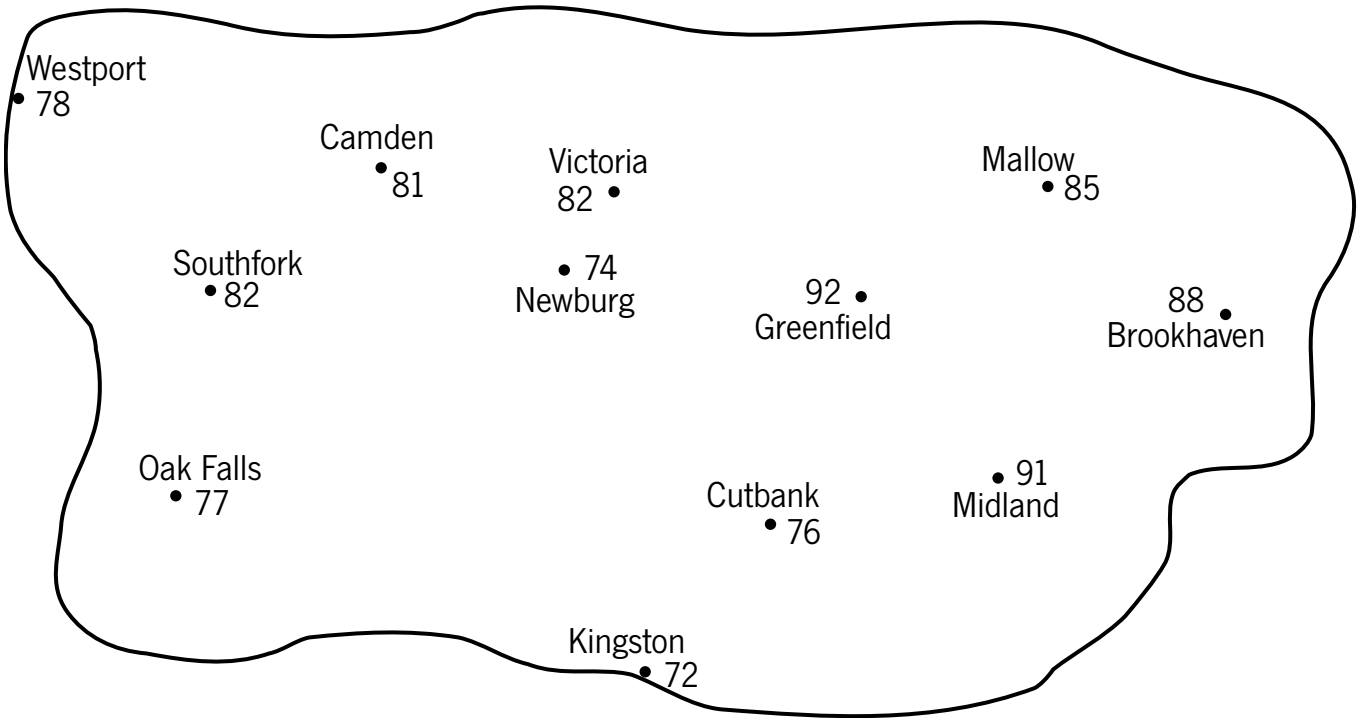
Heat Bands

Color the city points using the key. Draw the isotherms. Color the temperature bands.



40s	50s	60s	70s	80s	90s



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Heat Bands

below zero	0s	10s	20s	30s	40s	50s	60s	70s	80s	90s	100s

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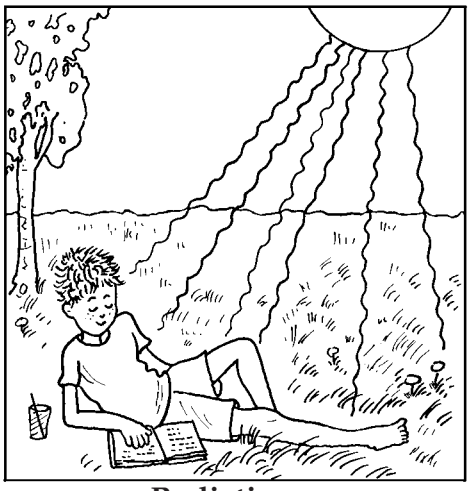
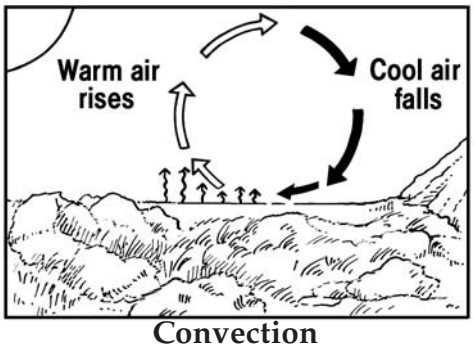
Heat Transfer

The sun's heat energy drives the weather on Earth. The transfer of heat occurs in three different ways: radiation, conduction, and convection.

Solar energy warms the Earth by **radiation**, the process whereby energy travels through space from one location to another. The sun's energy is transported by electromagnetic waves, mostly visible light with the remainder largely infrared radiation. Some of the energy is reflected (about 30%), some is absorbed in the atmosphere (about 20%), and some is absorbed by land and water on the Earth's surface (about 50%). When you feel the warmth of the sun or the warmth of a fire, you are experiencing radiation.



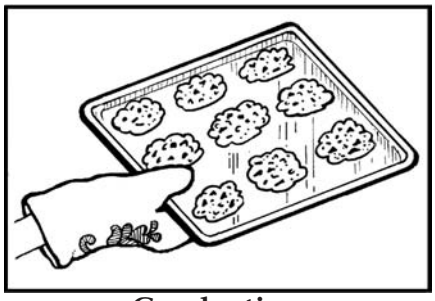
Radiation



Convection

Convection is the transfer of heat by the movement of a liquid or a gas such as air. As air is warmed at the surface of the Earth, it becomes less dense than surrounding air and rises. As the warm air reaches higher altitudes, it cools, then descends to begin the cycle again. This circulation is called a convection current; its source of energy is often a temperature difference. Hot air rising from the asphalt and water boiling on a stove are other examples of convection at work.

Conduction is the transfer of heat by direct contact, usually through solids. By conduction, heat energy travels along a metal spoon placed in hot soup. Because of conduction, the air in contact with the Earth's surface warms during the day and cools during the night. Air, however, is a poor heat conductor compared to metal.



Conduction

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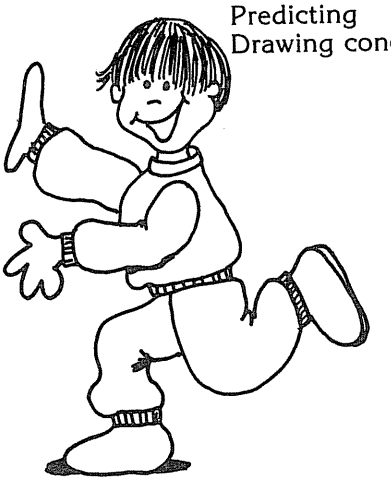
When HOT and COLD Meet

I. Topic Area
Physical Science—Hot and Cold Water

II. Introductory Statement
Students will observe hot water moving by convection.

III. Math Skills
Comparing

Science Processes
Observing
Communicating
Collecting/Recording data
Predicting
Drawing conclusions



IV. Materials
A large jar or small aquarium
2 small bottles or baby food jars
Red and blue food coloring
Hot water
Ice cold water
Room temperature water

V. Key Question
What happens when a small container of colored hot water and a small container of cold water is placed in a large container of room temperature water?

VI. Instructional Information
Heat tends to move from warmer objects to cooler objects. In convection, heat moves by currents of pathways in a fluid. When a fluid such as water is heated it expands or tends to spread out, thus becoming lighter and less dense.

In this activity, the hot colored water in the smaller jar is less dense and lighter than the surrounding cold water. The hot water is buoyed up or pushed upward by the cooler denser water. It rises and resembles smoke pouring from a chimney. The hot colored water tends to rise and then rest along the top or surface of the cooler water. If left long enough and the water is not disturbed, the colored water will then cool and fall to the bottom of the tank. Mixture of the two fluids will occur as their temperatures equalize.

The ice cold water is denser than the surrounding water, so the cold water settles to the bottom of the container. Some students may have experienced a temperature difference in a swimming pool or lake. As they dive toward the bottom, the water is much cooler than the surface water which has been warmed by the sun.

VII. Management Suggestions
1. The teacher may wish to use this as a demonstration and handle the hot water.
2. Use *CAUTION* when handling the hot water.
3. The large container should be filled with room temperature water.
4. The greater the difference in the temperature between the hot and cold water, the more dramatic the experiment will be.
5. When the small bottle of ice cold water is put in the large container, tip it on its side so the cold water can flow out.

VIII. Procedure
1. Fill an aquarium or large jar with room temperature water.
2. Fill the small bottle with hot water and add three drops of red food coloring. Cover the bottle with aluminum foil and put a rubber band around the neck.
3. Gently lower the small bottle into the large jar or aquarium.
4. Puncture the aluminum foil with a pencil point so the colored hot water can flow out. As the jar is put on the bottom of the aquarium and the foil punctured, a fountain of hot water will

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be released. Soon all the red colored water will be floating at the top of the room temperature water. This is because hot water has expanded and is lighter than the cold water so it rises to the top. (If the colored water doesn't flow out, you may have an air bubble trapped under the foil. Put two holes in the aluminum foil.)

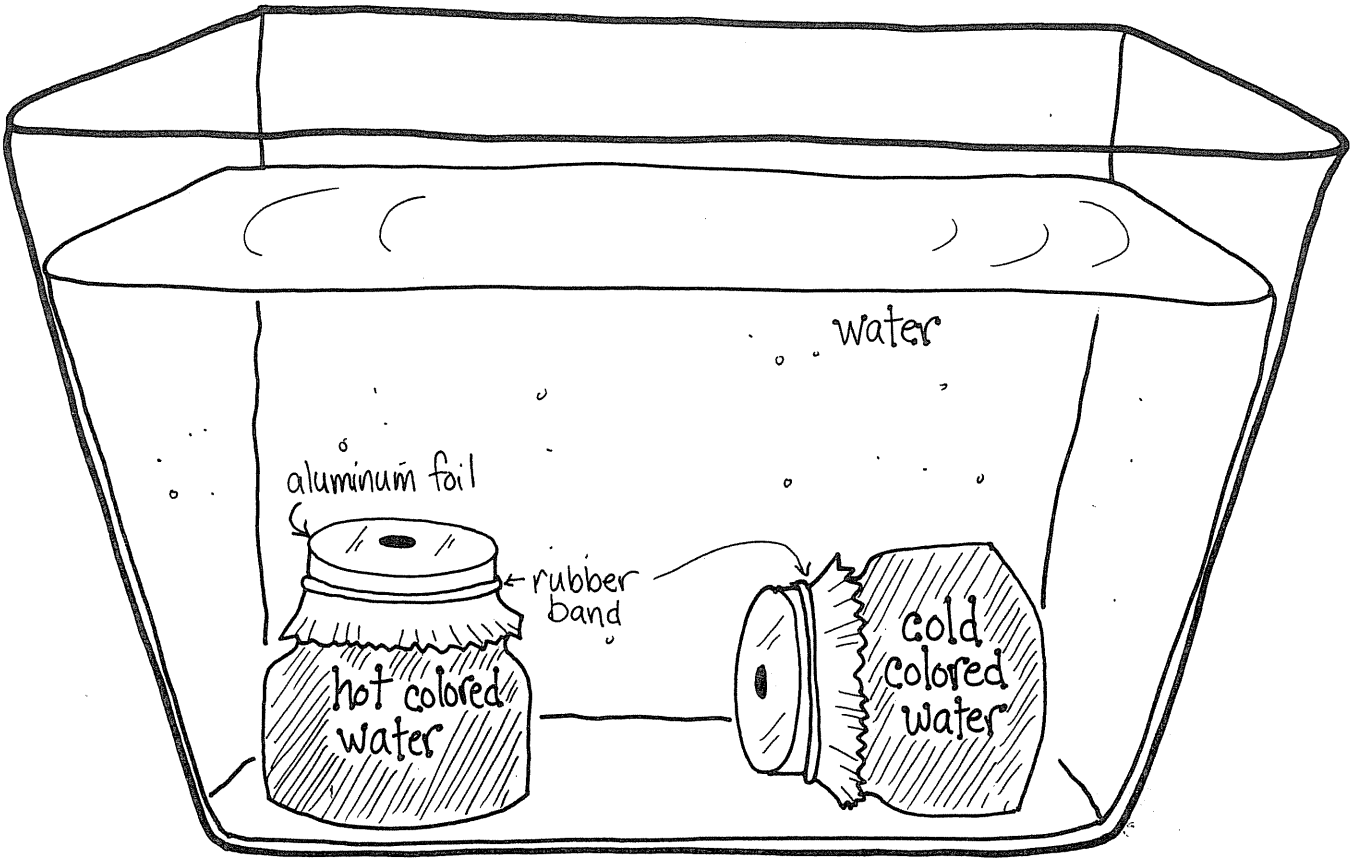
5. Have the students observe what is happening and draw the results on the worksheet.
6. Fill the other small bottle with ice water and add three drops of blue food coloring. Cover the bottle with aluminum foil and put a rubber band around the neck.
7. Gently lower the small bottle into the large container and puncture the aluminum foil. Tip the bottle on its side so the cold water can flow out on the bottom of the container.
8. Have the students observe what is happening and draw the results on the students sheet.
9. Then the students will explain on the bottom of the worksheet what they observed.

IX. Discussion Questions

1. Why does the colored hot water rise to the top of the aquarium and the cold stay on the bottom? (The hot water is lighter and less dense and so rises; the cold water is heavy and sinks to the bottom.)
2. What other material rises as it is heated? (air)
3. What would happen if the colored water in the container was left alone for one hour? (If the water is not disturbed, the hot and cold water will mix as their temperatures equalize and the colors will blend.)

X. Extension

1. Make colored ice cubes by adding food coloring to water, then freezing. As the cube melts, the colored water will stream from the cube to the bottom of the container. Try it!



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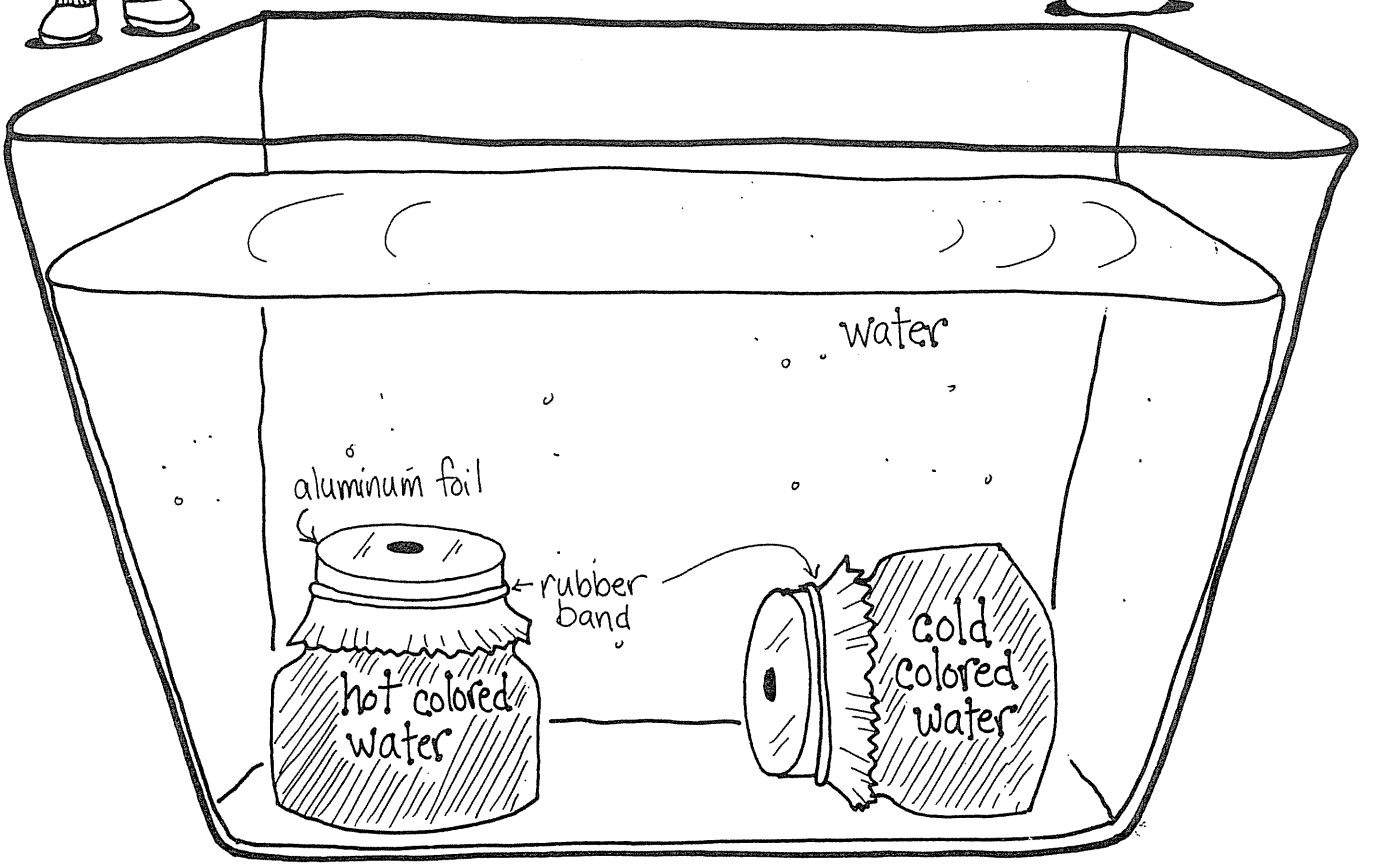
Name: _____

When HOT and COLD Meet

1. Put the bottle of hot colored water into the tank of water. Use a pencil to make a hole in the aluminum foil.

2. Put the bottle of ice colored water into the tank of water. Use a pencil to make a hole in the aluminum foil.



3 Write about what you saw happen. _____

_____

4. Why do you think this happened? _____

_____

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Colored Ice Cubes in Hot Water

Topic
Molecular motion of liquids at different temperatures

Key Question
What observations can be made when a colored ice cube is put in hot water?

Focus
Student will observe that the cold, colored ice water has a greater density than the hot water.

Guiding Document
Project 2061 Benchmarks

- *A model of something is different from the real thing but can be used to learn something about the real thing.*
- *Raise questions about the world around them and be willing to seek answers to some of them by making careful observations and trying things out.*
- *Describe and compare things in terms of number, shape, texture, size, weight, color, and motion.*
- *When warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all at the same temperature. A warmer object can warm a cooler one by contact or at a distance.*
- *One way to describe something is to say how it is like something else.*

Science
Physcial science
density

Integrated Processes
Observing
Comparing and contrasting
Generalizing
Applying

Materials
Colored ice cube
Hot plate
Pot or tea kettle
Glass container

Background Information
This activity should follow *Ice Cube in Water*. The general information is basically the same; however, it should be remembered that warm and hot water molecules are moving faster and are farther apart than cool and cold water molecules. Because of this, warm and hot water molecules are less dense than cool or cold water molecules. When the colored ice cube is placed in the hot water, it will sink lower into the water than when placed in a container of cool or cold water.

Management
1. A day or two before conducting the activity, add food coloring to some water before pouring it into an ice cube tray.
2. A hot plate is not needed if hot water can be drawn from the tap.
3. An empty quart jar works well for a container for this activity.

Procedure
1. Prior to conducting this activity, have the students discuss what they think the results will be. Ask them to justify their predicitions by telling why the results might be as predicted.
2. Heat the water in a pot.
3. After letting the water cool for awhile, pour it into a glass container. (If water is too hot, it might break the glass.)
4. Put a colored ice cube in the container of water.
5. Observe.

Discussion
1. How hot does water have to be before it boils? [At sea level (14.7 pounds per square inch - PSI) distilled (pure) water boils when its temperture reaches 212° F or 100° C. If the water has dissolved impurities in it, it requires a higher temperature before it will boil. At altitudes above sea level, water will boil at temperature less than 212° F (100° C).]
2. How cold must water be before it turns to ice? [Distilled water turns to ice when its temperature reaches 32° F (0° C). Impure water requires a lower temperature before it freezes.]

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3. What happens when the ice cube was placed in the water? Why? [When the ice cube was placed in the water, it began to melt. The heat from the water caused the solid (ice) to turn to a liquid (water). The liquid (cold water) was heavier than the warm water around it so it sank to the bottom. The colored ice water could be seen flowing down to the bottom.]
4. What does this activity demonstrate? [This activity demonstrates two things:
   a. Ice is lighter than the same volume of water and it will float when placed in water.
   b When the ice changes to water, the water is cooler (more dense) than the warmer water around it. When warm and cool water mix, the cool water will flow to the bottom.]
5. Apply what you have learned to water in oceans and lakes.

Extensions

1. Ask students to suggest ways that they might observe ice (or cold water) reacting in the way observed in the activity. [Responses might include that ice forms and floats on the surface of frozen lakes or streams. Ice will float when placed in water or beverages. In a swimming pool, the cold water is at the bottom and the warmer water is near the surface. This concept can also be related to warm and cool air. The second floor of a two-story house is warmer than the first floor because warm air rises.]
2. Ask what will happen to the container of water after the ice cube has melted. [The current caused by the mixing of cold and warm water will result in an even distribution after a period of time.]
3. Place a thermometer in the water. How does the temperature of the water compare with the room temperature after one minute?...one hour?...one day?...three days?
4. Have students research to determine at what altitude water will boil when its temperature is 32° F.

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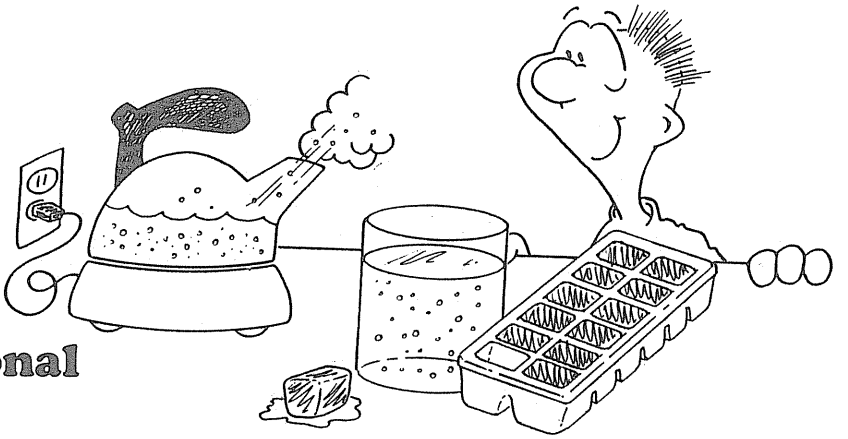
Colored Ice Cubes in Hot Water



Materials:

Colored ice cube
Hot plate
Pot or tea kettle
Glass container
Thermometer, optional

Procedure:

(The day before this activity, put some colored water in an ice cube tray and place it in the freezer.)

1. Boil water in a pot.
2. After letting the water cool for awhile, pour it into a glass container. (If the water is too hot, it might break the glass.)
3. Put a colored ice cube in the container of water.
4. Observe.

Questions:

1. How hot does water have to be before it boils?

2. How cold must water be before it turns to ice?

3. What happened when the ice cube was placed in the water? Why?

4. What does this activity demonstrate?

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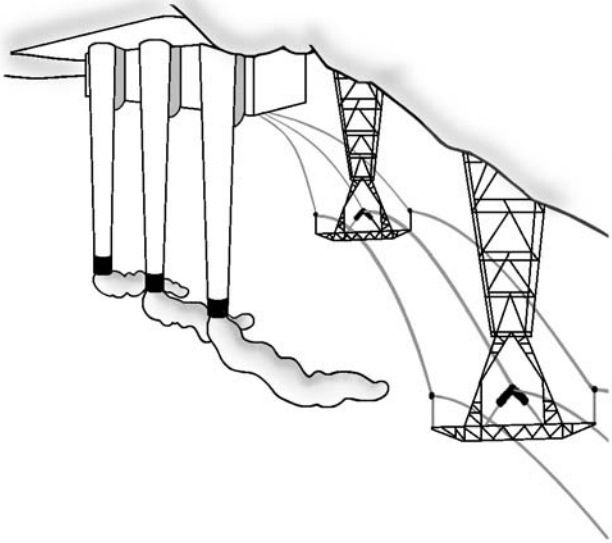
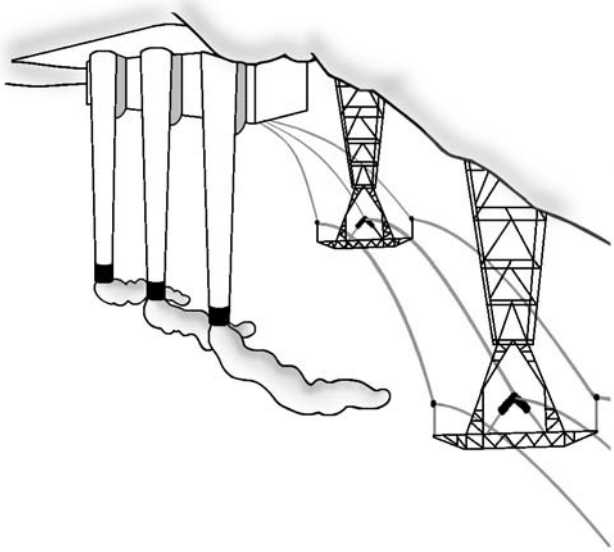
Natural Resources, Renewable and Nonrenewable

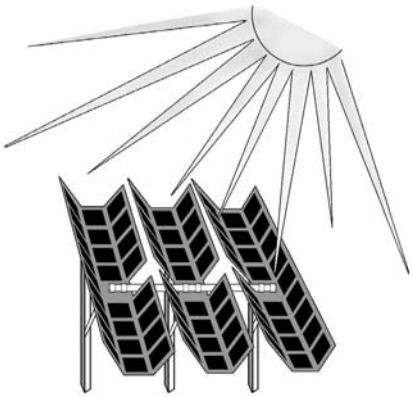
What are natural resources? Natural resources are supplies from nature. Years ago people thought the term meant only sources of energy in the environment. This included things like coal, iron, timber, and rivers. As our knowledge about Earth has increased, the term now applies to almost everything on Earth, along with sunlight, that is considered useful or necessary for our lives.

Water supplies also depend our on actions. The amount of water on Earth never changes, but we might change the amount that we can use in a certain area. We might pollute it to the point that we can't use it. Or we might pump too much out of a large underground reservoir that took thousands of years to build up that supply. Nature would not be able to refill it fast enough.

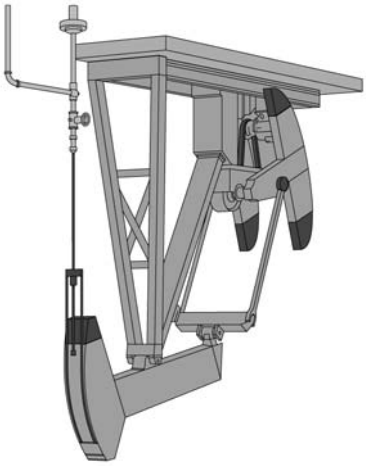


With all resources, renewable or nonrenewable, it is our responsibility to use them wisely.





Natural resources are often divided into two categories, renewable and nonrenewable. Renewable resources are those things that can be reused or replaced as fast as they are used. Solar energy is a renewable resource because no matter how much we use, there is always more. Wind energy is another renewable resource.



Nonrenewable resources are those things that cannot be renewed as quickly as they are used. Oil is a nonrenewable resource because it takes millions of years for oil to form. We use it much faster than it is formed. Coal is another nonrenewable resource.

Some resources like fresh water, soil, trees, and wildlife are hard to fit into a definite category of renewable or nonrenewable resources. These resources rely upon us to use them wisely. If we do, they will be available for our use. If we don't use them wisely, we are in danger of limiting their supply.

Take wildlife for example. If an animal species is over-hunted or if its habitat is destroyed, its population may decline or it may become extinct. It is our responsibility to make wise decisions on how to protect animals and their habitats.

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Topic
Application of percentage into a class recycling project.

Key Questions
1. At the end of each school month, how many pounds of aluminum will our class have collected?
2. Of the sample collected, which type will have the highest percentage?

Learning Goals
Students will:
- use a recycling project to reinforce concepts concerning collection of data and conversion into percents, and
- become more aware of recycling issues.

Guiding Documents
Project 2061 Benchmarks
- *Graphical display of numbers may make it possible to spot patterns that are not otherwise obvious, such as comparative size and trends.*
- *Use numerical data in describing and comparing objects and events.*
- *Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.*

NRC Standards
- *When an area becomes overpopulated, the environment will become degraded due to the increased use of resources.*
- *Causes of environmental degradation and resource depletion vary from region to region and from country to country.*

*NCTM Standards 2000**
- *Develop fluency in adding, subtracting, multiply, and dividing whole numbers*
- *Recognize and generate equivalent forms of commonly used fractions, decimals, and percents*
- *Collect data using observations, surveys, and experiments*
- *Represent data using tables and graphs such as line plots, bar graphs, and line graphs*

Math
Estimation
Graphing
  point, bar, and circle
Whole number computation
Fractions
Decimals
Percent

Science
Earth science
  resources
    recycling
Safety

Materials
Student sheets
Pencils and crayons
Protractors
Aluminum cans
Plastic gloves
Barrel
Plastic garbage bags
Newspaper
Whole group graphs

Background Information
The aluminum beverage can was introduced in 1965. By 1985 it surpassed all other materials used for beverages. Some of the benefits of aluminum are:
- It can be molded without a seam interrupting the beverage's advertisement.
- It is strong enough to withstand the pressure exerted by carbonation.
- It's lightweight.
- It is resistant to rust.
- It's aluminum tab was easy to manufacture.
- It can be recycled very efficiently.

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In the late 60s, there was a "Ban the Can" campaign because aluminum cans were adding a great deal of litter to the environment and increasing the amount of trash being picked up. Manufacturers took note of the complaints and discovered the added benefits to the lower manufacturing costs if they used recycled aluminum. Environmentally, recycling saved the natural resources, mainly bauxite, which were used to make the cans.

With the celebration of the first Earth Day in 1970, recycling of aluminum cans began to take hold. Today, the recycling of aluminum cans is a billion-dollar business with over 60 percent of the aluminum cans being recycled. More than 2 billion pounds of aluminum are kept from filling landfills. Making cans from recycled aluminum saves 95 percent of the energy needed to make cans from the raw materials. These savings to the manufacturer result in savings that are passed along to consumers.

Management

1. Estimated time: one 60-minute session for the classification of the cans with another 30-minute follow-up the next day. (This activity is done monthly throughout the year.)
2. The class is divided into five teams of six members each to help expedite the classification and counting process.
3. Students are responsible for group cooperation while doing the classification and counting process.
4. Students will use worksheets for the collection of data.
5. At the beginning of the year, students can use calculators to facilitate the conversion of fractions into decimals and decimals into percents.

Procedure

1. Ask the *Key Questions* and state the *Learning Goals*.
2. Tell the students that they will collect aluminum cans each month to deposit in the barrel in the classroom.
3. At the end of the month, the students will be asked how they would like to classify the types of cans for the month. To begin this project, try to keep the number of types to around five.
4. Move the desks out of the way and spread the floor with newspapers or weather permitting do this part of the activity outside on the blacktop.
5. Go over safety procedures and distribute plastic gloves.
6. With students divided into small groups, give each group part of the can collection for classifying and counting.
7. Have students record the data on the tally worksheet.
8. After completing the can classifying and counting, ask students to place the cans into large plastic garbage bags and close off the tops.
9. On a large piece of butcher paper, have students record data for each type of collected can. Ask students to copy data onto individual data sheets.
10. Direct students to complete the column addition for each type and record class totals.
11. Have them complete individual bar graphs for the totals, making a decision on the intervals to be used on the graph.
12. Have students then complete the table, converting types into fractions, decimals, and percents.
13. After the cans have been returned to the recycling center, invite the class to meet in a whole group situation to complete the activity sheets and the point graph for the month.
14. Each month a different small group should be asked to work on completing the circle graph for the percentages of types of cans.

Connecting Learning

1. How can we classify the aluminum cans collected this month?
2. After observing the number of cans per type, what are some statements we can make about the sample of cans collected?
3. After observing the nine months of data, are there any months where the amount of cans varied? What may be responsible for this variance?
4. What are some uses of recycled aluminum?
5. Why do people recycle?
6. What could we do with the money collected from our recycling project?
7. What are you wondering now?

Extensions

1. Take a field trip to the different recycling centers available in the area.
2. Do a creative or factual writing assignment following the life of an aluminum can.
3. Tie the activity into a recycling project as part of many ways in which we can recycle.
4. Do a playground cleanup project and collect and sort types of garbage collected and repeat above activity. Display with a caption concerning eliminating this problem.
5. Research with local beverage distributors the problems involved with states who have deposits on aluminum cans.

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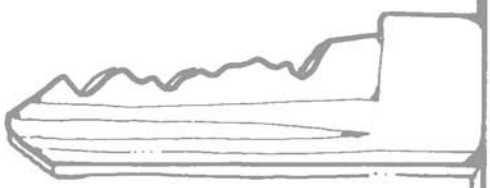

Key Questions

1. At the end of each school month, how many pounds of aluminum will our class have collected?
2. Of the sample collected, which type will have the highest percentage?

Learning Goals

Students will:

- use a recycling project to reinforce concepts concerning collection of data and conversion into percents, and
- become more aware of recycling issues.

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Environmentalist _____

Let's Recycle

Part One

How will we sort and classify our sample?

Make a prediction: Which group will have the greatest number?

_____ ...the least number? _____

How many pounds of aluminum do you think we collected during

_____?
(month)

_____ lbs.

How many actual pounds were collected?

_____ lbs.

How many cans were collected during _____?
(month)

_____ cans.

Aluminum is currently paying _____ per lb. Each can is

worth _____.

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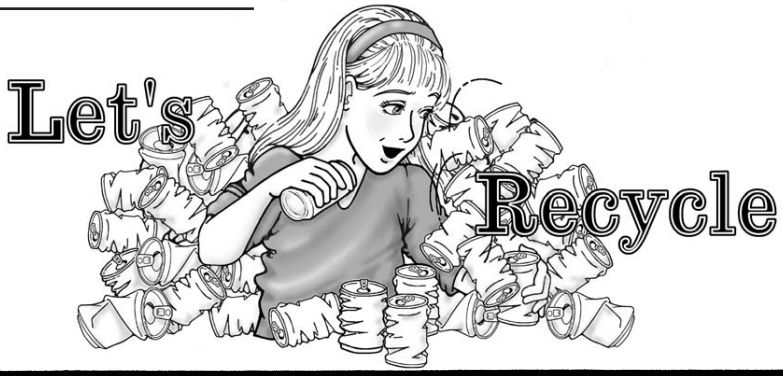
Environmentalist _____



Part Two

Types of Cans	Tally	Group Total	Class Total
		Total for the Month	

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Let's Recycle

Environmentalist _____

Part Three

Types of Cans	No. of Cans	Part/ Whole	Decimal Equivalent	Percent Equivalent

For the month of _____ (month), _____ (number) cans equal 100%

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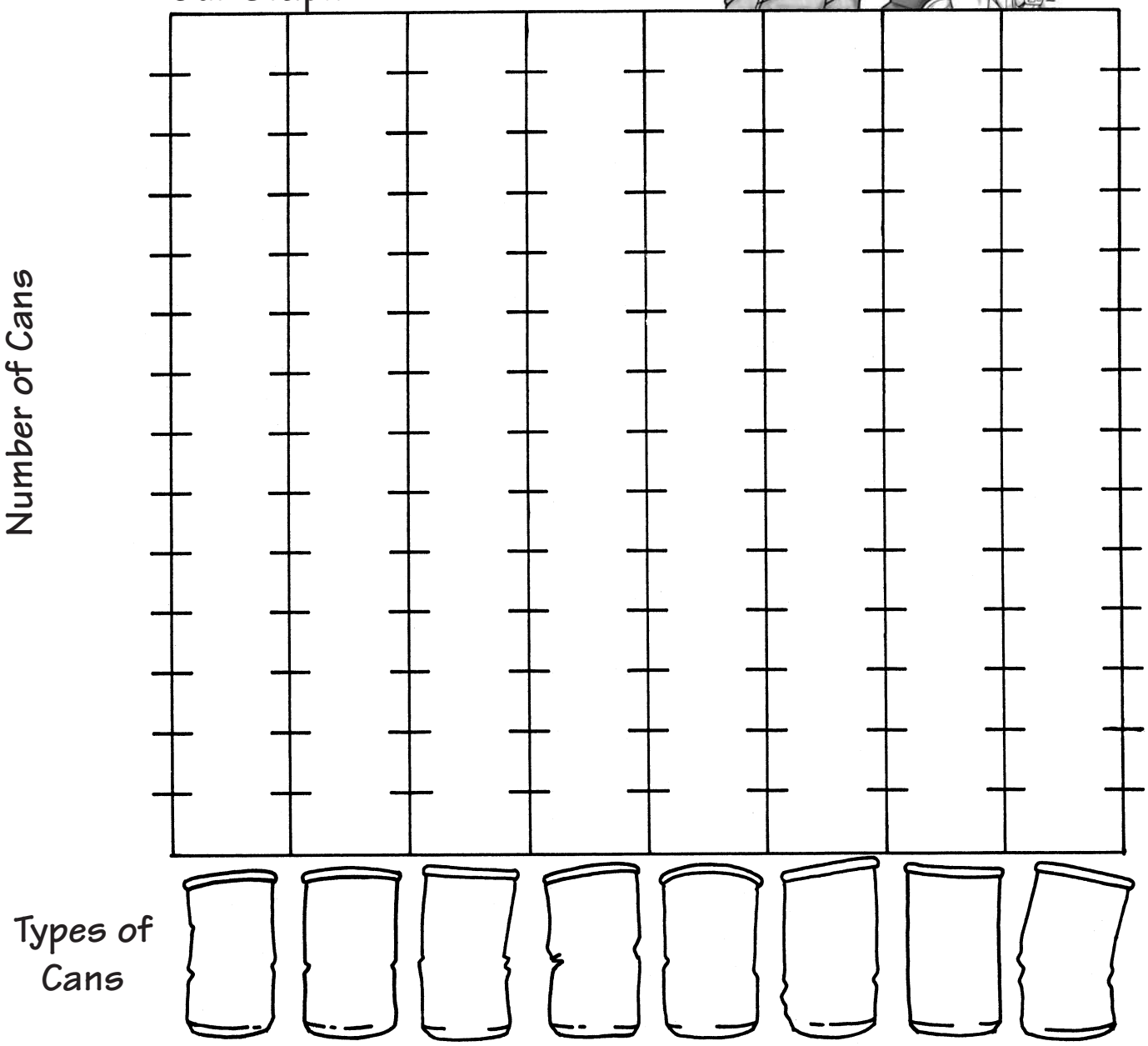
Environmentalist _____

Let's Recycle

Part Four

Our Graph



Summarize the results on the back of this paper.

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Let's Recycle

Connecting Learning

1. How can we classify the aluminum cans collected this month?

2. After observing the number of cans per type, what are some statements we can make about the sample of cans collected?

3. After observing the nine months of data, are there any months where the amount of cans varied? What may be responsible for this variance?

4. What are some uses of recycled aluminum?

5. Why do people recycle?

6. What could we do with the money collected from our recycling project?

7. What are you wondering now?

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Mini Water Treatment Simulation

Topic
Water treatment

Key Question
How is water from the natural water cycle purified for home use?

Learning Goal
Students will do an activity that simulates the steps in the water treatment process.

Guiding Document
NRC Standards

- *Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.*
- *When an area becomes overpopulated, the environment will become degraded due to the increased use of resources.*

Math
Measuring

Science
Earth science
natural resources

Integrated Processes
Observing
Comparing and contrasting
Applying
Generalizing

Materials
For the class:
water, 1 cup
dirt, 2/3 tsp.
2 clear plastic cups, 10-oz.
Styrofoam cup
paper towels
powdered alum, 4 oz.
clean sand, 1/2 to 2/3 cup
clean gravel, 1/4 cup (optional)
yellow food coloring

Background Information
A water company must go through several steps to insure safe and pure drinking water for a community. The water that is processed comes from the natural water cycle and has usually been transferred and stored in a reservoir before processing.

The following steps are found in a typical water treatment plant:

Aeration: Water is sprayed into the air to release any trapped gases and to absorb additional oxygen.

Coagulation: To remove dirt suspended in the water, powdered alum is dissolved in the water and it forms tiny, sticky particles called "floc" that attach to the dirt particles. The combined weight of the dirt and the alum particles (floc) becomes heavy enough to sink to the bottom during sedimentation.

Sedimentation: The heavy particles (floc) settle to the bottom and the clear water above the particles is skimmed from the top and is ready for filtration.

Filtration: The clear water passes through layers of sand, gravel, and charcoal to remove small particles.

Chlorination: A small amount of chlorine gas is added to kill any bacteria or microorganisms that may be in the water.

Management

1. This activity may be done without adding the alum. However, if you do add the alum, it produces much clearer water. Alum is quite inexpensive and may be purchased at any drug store. If it is not in stock, ask the manager to order it for you. The alum creates "floc" that may take 10-15 minutes to settle to the bottom.
2. Clean sand may be purchased from any hardware store or home-supply store. If you use sand or gravel from the playground, be sure to rinse it well first to remove any dirt.
3. Students will use a sharpened pencil to poke 10 small holes in the bottom of the Styrofoam cup to which the clean sand will be added and used as a filter.
4. A piece of paper towel may be used to line the Styrofoam cup to prevent the sand from coming through the holes.
5. A series of Styrofoam cups may be stacked one on another to make the most efficient Styrofoam filtering system. Each cup could contain a separate material through which to filter the water.
6. Make a mixture of 2 drops of yellow food coloring in water to simulate adding chlorine for purification.

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7. Add 2/3 tsp. to one cup of water to make the dirty water mixture used in this activity.

Procedure

1. State the *Key Question* and *Learning Goals*.
2. Discuss water purification. Inform students that in order to have safe and pure drinking water, the local supply must go through several steps in a treatment process.
3. For each group distribute one clear plastic cup with water that has 1/2 teaspoon of dirt mixed in it. Tell them that water that has come through the natural water cycle might not be as dirty as this sample.
4. Hand out the activity sheets to each student; review the steps in the water treatment process.
5. Ask one person from each group to gather the materials they will need.
6. Have the students poke 10 small holes in the bottom of the Styrofoam cup. This will contain sand and be used as a filter cup. Have extra cups available for more elaborate filtering systems. Have the students record their observations on the activity sheet.
5. Students should add 1 or 3 drops of **simulated** chlorine bleach to each groups final water sample. **CAUTION: Do not use real bleach or drink the water!**

Connecting Learning

1. Which part of the process do you think had the greatest impact on cleaning the water?
2. Why aren't you allowed to drink the water in this simulation?
3. Where does your drinking water come from?
4. How do the cleaned samples compare?
5. What steps did your group take to purify their water?
6. What do you think would have happened if the steps were done in a different order?
7. How could we find out how our local water is purified?
8. What are you wondering now?

Extensions

1. Students can write letters or phone their local water company asking them to send literature or have a representative visit the class to explain local water treatment procedures.
2. Go on a field trip to the local water facility.
3. Invent their own water purification system using other common objects they may have at home.

Optional Lesson

Water Treatment Plant—see activity sheet.

a. Cut out each square in rows 2, 3, and 4.
b. Arrange them in the proper order of a water treatment plant.
c. Tape all of the squares together in a long strip and pass it through the slits on the top row.
d. The correct order is:
    1. incoming water
    2. aeration;
    3. alum;
    4. coagulation;
    5. sedimentation;
    6. filtration;
    7. chlorination;
    8. storage;
    9. to homes.

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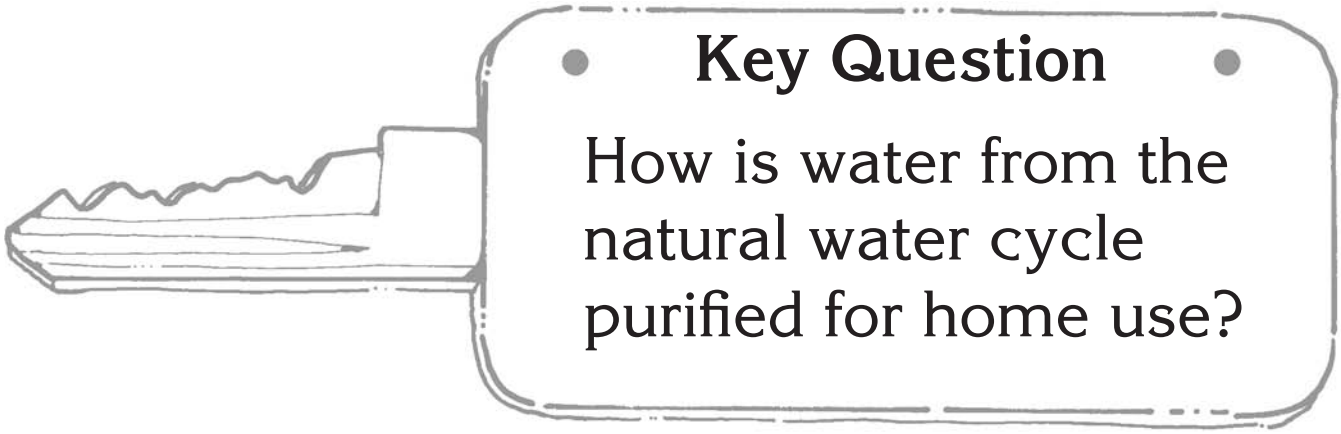
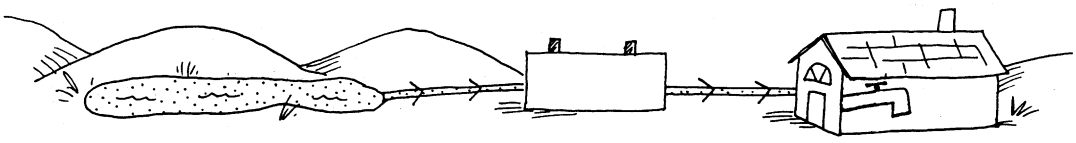
Mini Water Treatment Simulation



Learning Goal

Students will:

simulate the steps in the water treatment process.



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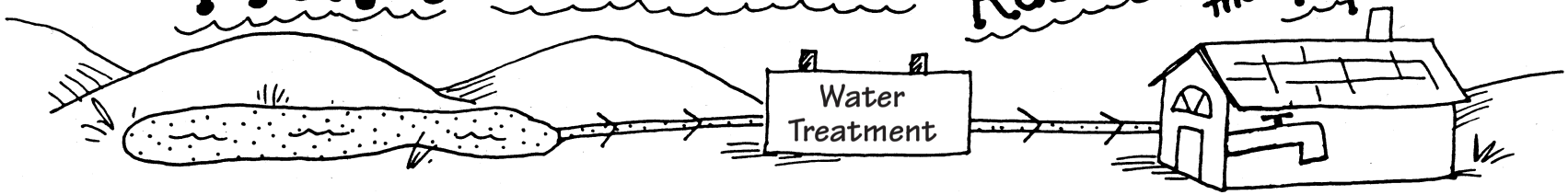
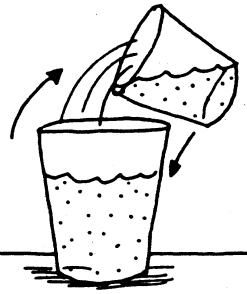
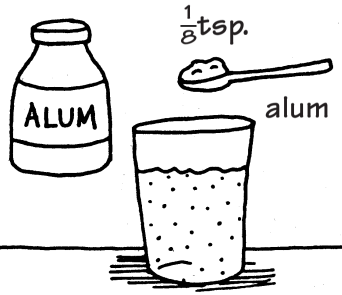
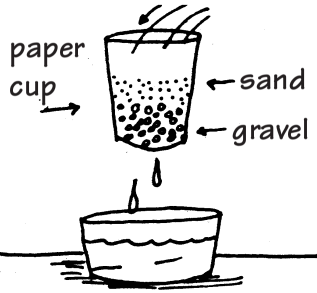
Water Treatment from the Reservoir to the Tap!



Step 1 **Aeration:**	Step 2 **Coagulation:**	Step 3 **Sedimentation:**	Step 4 **Filtration:**	Step 5 **Disinfection:**
				
Aerate water to release trapped gas.	Alum collects small dirt particles forming larger sticky particles call "floc."	The larger "floc" particles settle to the bottom.	The "floc" particles are trapped in the layers of sand and gravel.	A small amount of disinfectant is added to kill the remaining bacteria. The microorganisms are killed by this process. Do not do this step.
Observation:	Observation:	Observation:	Observation:	

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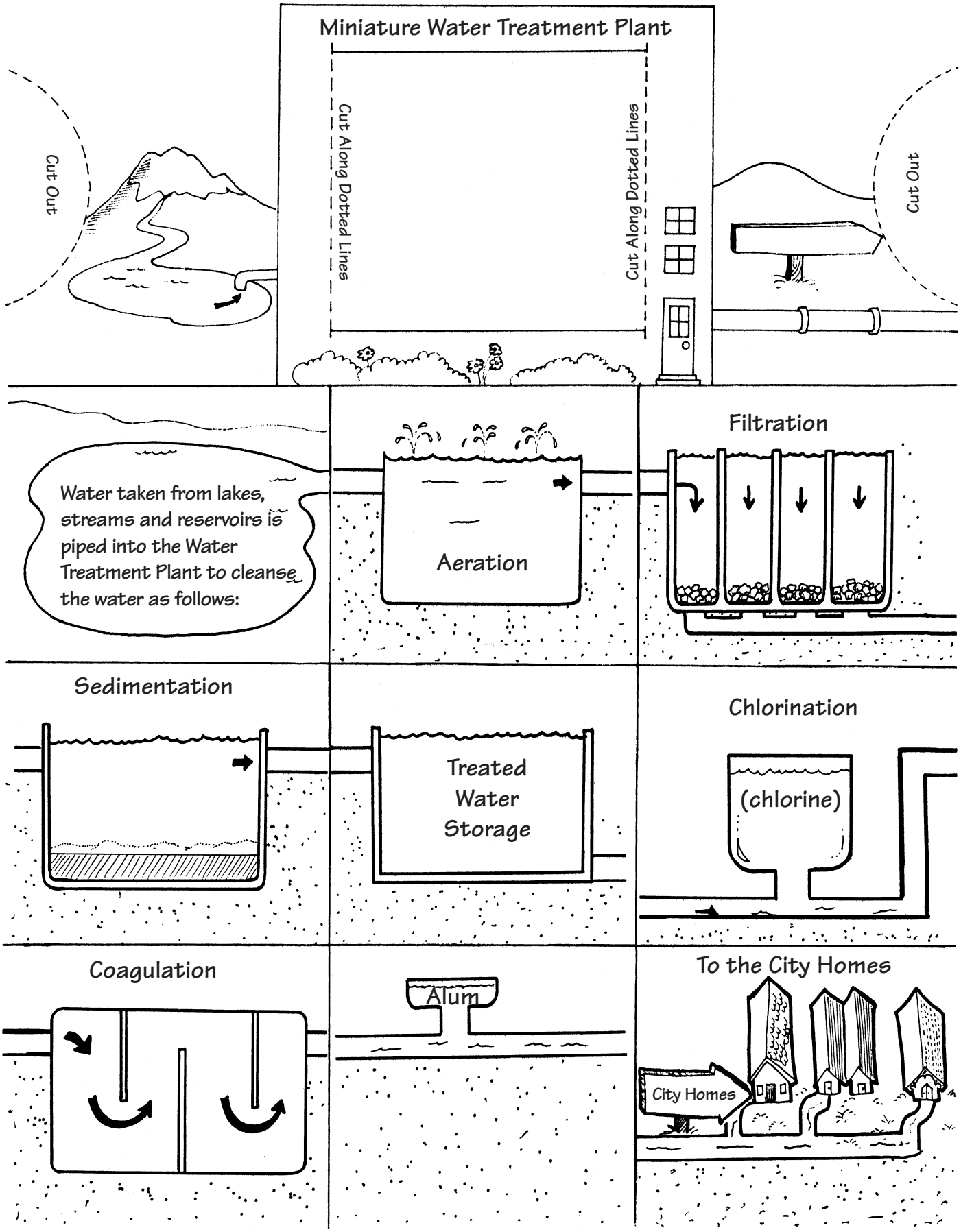

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Mini Water Treatment Simulation

Connecting Learning

1. Which part of the process do you think had the greatest impact on cleaning the water?
2. Why aren't you allowed to drink the water in this simulation?
3. Where does your drinking water come from?
4. How do the cleaned samples compare?
5. What steps did your group take to purify their water?
6. What do you think would have happened if the steps were done in a different order?
7. How could we find out how our local water is treated?
8. What are you wondering now?

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Measuring Trees

Topic
Natural resources

Key Question
How many trees have to be cut down to build a house?

Learning Goals
Students will:
- recognize that natural resources, such as lumber, are limited;
- realize that conservation of natural resource requires both wise use and active improvement; and
- learn to estimate the amount of lumber in a tree.

Guiding Documents
Project 2061 Benchmarks
- *Measuring instruments can be used to gather accurate information for making scientific comparisons of objects and events and for designing and constructing things that will work properly.*
- *In something that consists of many parts, the parts usually influence one another.*

NRC Standards
- *Causes of environmental degradation and resource depletion vary from region to region and from country to country.*
- *Use mathematics in all aspects of scientific inquiry.*

*NCTM Standards 2000**
- *Select appropriate methods and tools for computing with whole numbers from among mental computation, estimation, calculators, and paper and pencil according to the context and nature of the computation and use the selected method or tools*
- *Select and apply appropriate standard units and tools to measure length, area, volume, weight, time, temperature, and the size of angles*
- *Understand the need for measuring with standard units and become familiar with standard units in the customary and metric systems*

Science
Environmental science
  conservation
    limited resources—lumber

Math
Measurement
  length
Multiplication
Estimation

Integrated Processes
Observing
Collecting and organizing data
Predicting
Inferring
Interpreting data
Communicating

Materials
50-100 ft. tape measure
String
Clinometer (*Tree Transit*)
  card stock
  paper clips
  pin
  tape
  straw

Background Information

About 100 years ago, the forest was exploited as an inexhaustible resource. Today the forest industry plans for the future. Modern forestry includes extensive reforestation projects, continuing research on tree disease, and creative land use protection.

In order to insure a continuing crop of trees for future generations, new logging practices have been enacted. In some areas, selective cutting is used while in other areas, clear cutting is practiced in order to reduce the competition between young replanted trees and more mature trees.

It is also important to determine the expected yield of a stand of trees. To do this, forest professionals called timber cruisers are employed to survey, mark, and estimate the number of board feet in a given location or in a specific tree. This activity is a modified method of one way timber cruisers determine the board feet in a tree.

To estimate the board feet in a tree, one needs to know its girth (circumference) at breast height (4.5 ft. = 54 in.), and the number of logs (16 feet) in its height. In the field, a timber cruiser usually uses a Biltmore stick, which was developed using trigonometry, and stands a chain (66 feet) from the tree. This activity has been modified so that the student uses a *Tree Transit* instead of a Biltmore stick. The transit measures angle of elevation, but its scale converts it to a length measurement such as number of logs. The

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scale on the transit was developed using trigonometry. It is designed to be used 50 feet from the base of the tree. Using a table with the girth and number of logs, the students can estimate the board feet harvested from a tree. (The usable board feet of lumber varies greatly between varieties of trees. The table used in this activity is based on general table for conifers.)

Lumber for the construction of houses is a major use of timber in the United States. Wood is used in the framing, trimming, and cabinetry of a home. The depletion of timber has driven up the cost of wood. Alternative materials such as steel studs and composite materials are being used to reduce the use of wood or make better use of waste wood.

Management

1. Each group of students will need a *Tree Transit*. Follow the instructions below to make a transit for each group.
   a. Copy the transits onto card stock.
   b. Cut out each transit around the bold line.
   c. Use a pin to make a small hole at the intersection of the lines in the small circle.
   d. Thread an end of a 10-inch string through the hole and secure about an inch to the back.
   e. Tie a paper clip to the loose end of the sting so it is free to swing in front of the transit.
   f. Tape a straw on the top of the transit as the sight.
   g. The string and paper clip act as a plumb line. Adding a penny to the paper clip will produce better results.
2. Before measuring the tree height, the students need to be instructed in the use of the transit.
   a. Locate a position 50 feet from the base of the tree.
   b. While lying on the ground (either stomach or back down) sight the top of the tree through the straw. The line must be free to swing across the scale. The sighter must be sure that his or her fingers or the transit itself does not stop the string from free motion.
   c. While the sighter holds the transit with the sight lined up with the top of the tree, another student sees where the plumb line hangs to determine the number of logs in a tree.
3. If conditions warrant, students may stand to make a sighting. They will need to add their eye-height to the tree height shown on the transit.
4. Find an appropriate tree to measure before class. Its girth at breast height (54 in.) must be 36 in. or greater. It needs to have a height of at least 48 feet. The larger the tree, the better.

Procedure

1. Have the students consider and discuss the *Key Question* and have them make a prediction. State the *Learning Goals*.
2. If appropriate, instruct students in the use of the transit.
3. Take the class to the appropriate tree(s) and have them wrap a string around the circumference of the tree at 4.5 feet above the ground. Have them measure and record the length of the string in inches as the circumference by measuring the string.
4. Have each group locate a position 50 feet from the base of the tree and use their transit to measure and record the number logs in the height of the tree.
5. Using their measurements for circumference and height in logs, direct the students to refer to the chart and circle the number of board feet that best fits their measurements.
6. Using their estimation of board feet in the tree, have the students determine the number of trees required in building a house. Students might use a calculator, if appropriate.
7. Have students return to their original prediction and compare it with their estimation from measurements. As a class, discuss what could be done to use fewer trees and what could be done to increase or maintain our supply of lumber.

Connecting Learning

1. What surprises you about the amount of trees needed to build a house?
2. What can be done so that fewer trees are needed to build homes? [use alternative materials, recycle material, use all parts of the tree better (composite materials), reduce the size of homes]
3. What can be done to improve the forests? [cut wisely, prevent disease, replant, thin for proper use]
4. How can you reduce the use of trees?
5. What are you wondering now?

Extensions

1. Determine how many trees are required for a home for every student in your class, and school.
2. Have students find out how many square feet in their home or apartment and use the information to estimate the number of trees that were cut down to build their home.

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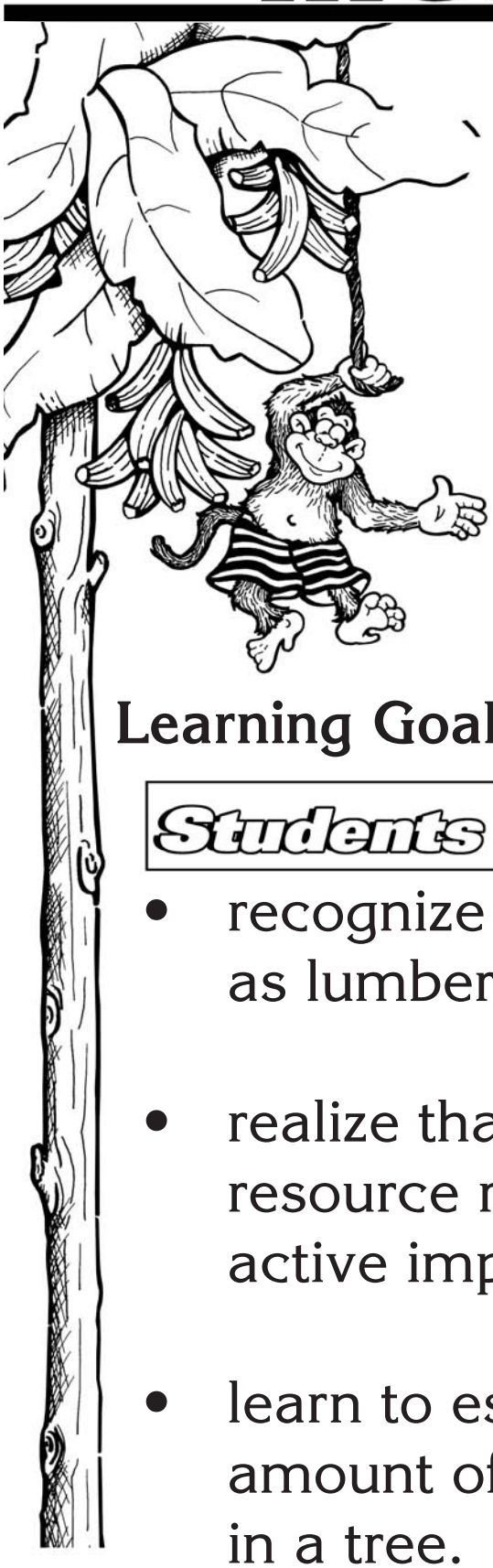
Measuring Trees



Key Question

How many trees have to be cut down to build a house?

Learning Goals

Students will:

- recognize that natural resources, such as lumber, are limited;
- realize that conservation of natural resource requires both wise use and active improvement; and
- learn to estimate the amount of lumber in a tree.

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Measuring Trees

How many trees have to be cut down to build a house?

A. Use a string and tape measure to determine how many inches around (circumference) the tree is. _____
Circumference

B. Find a spot 50 feet from the bottom of the tree and use your Tree Transit to measure how many logs (16 feet) high the tree is. _____
# of 16 foot logs

C. Using the chart and your measurements for circumference and number of logs in the height, find the amount of board feet in the tree. Circle the number of board feet that is the best estimation for your measurements.

Circumference at breast height (inches)	Number of 16 foot logs: 3	4	5	6	7	8
36	115					
42	145	210				
48	180	260	285			
54	220	315	410			
60	260	370	490	630		
66	305	430	610	765	900	1030
72	355	505	715	880	1050	1220
78	400	600	830	1050	1250	1440
84	480	716	975	1185	1480	1730
90	580	859	1160	1450	1760	2050

Approximate boardfeet of lumber

Approximate boardfeet of lumber

D. A 2000 square house needs 4000 board feet of lumber for framing and an additional 3000 feet for trim and cabinets. Calculate how many trees are needed to frame and build a 2000 square foot home.

_____ (framing) + _____ (trim and cabinets) = _____ (board feet needed)

_____ (board feet needed) ÷ _____ (board feet per tree) = _____ (trees per house)

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Measuring Trees

Sighting Straw

Tree Transit

USE 50 FT. FROM TREE

10 20 30 40 50 60 70 80 100 140 Feet

1 log
2 logs
3 logs
4 logs
5 logs
6 logs
7 logs
8 logs

Sighting Straw

Tree Transit

USE 50 FT. FROM TREE

10 20 30 40 50 60 70 80 100 140 Feet

1 log
2 logs
3 logs
4 logs
5 logs
6 logs
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Connecting Learning

1. What surprises you about the amount of trees needed to build a house?

2. What can be done so that fewer trees are needed to build homes?

3. What can be done to improve the forests?

4. How can you reduce the use of trees?

5. What are you wondering now?

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Being Resourceful

1. List two nonrenewable resources and tell why they are considered nonrenewable.

2. What can we do to show we are responsible with water?

3. Name something you can
   reuse

   recycle

   reduce

4. What resource are you most interested in protecting? Explain why.

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Trail Blazers

Topic
Orienteering: magnetic compass

Key Question
How can you use a compass to find your way to a certain location?

Focus
Students will use a magnetic compass and a set of instructions to find the location of a "treasure."

Guiding Documents
National Geography Standard
- *Knows and understands how to use appropriate geographic tools and technologies*

Project 2061 Benchmark
- *It takes two numbers to locate a point on a map or any other flat surface. The numbers may be two perpendicular distances from a point, or an angle and a distance from a point.*

NCTM Standards
- *Develop an appreciation of geometry as a means of describing the physical world*
- *Extend their understanding of the process of measurement*
- *Relate geometric ideas to number and measurement ideas*

Social Science
Geography

Math
Measurement
  angle
  length
Estimation
Spatial sense

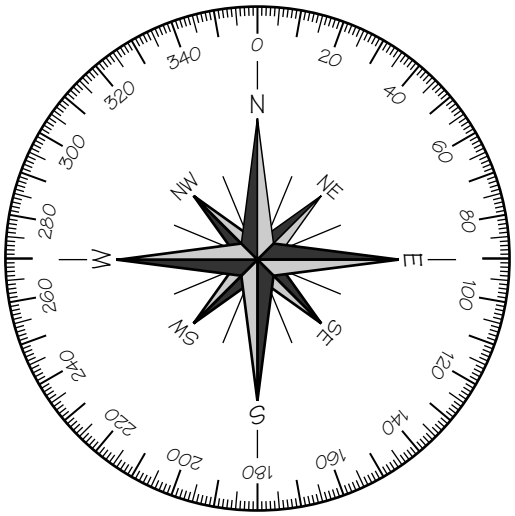
Technology
Tools

Integrated Processes
Observing
Interpreting data
Applying

Materials
Magnetic compass
Chalk or string and paper (see *Management 1*)

Background Information
The Earth is a large magnet with a north and a south magnetic pole. A magnetized needle floating free will be aligned north and south because of the Earth's magnetic field. This principle has been used to make magnetic compasses.

A magnetic compass can be compared to a protractor as they both divide circles into 360˚. Students should begin to realize that when a circle is divided into four equal sectors, each sector contains a 90° angle. When applied to a magnetic compass, these 90° angles designate the cardinal directions.



The skills learned from using a magnetic compass can be applied to angle measure, map reading, and orienteering.

Management
1. Have students work in groups of three. One student will read the directions, another will use the compass and blaze the trail, the third will record the path of the trail blazer by drawing a chalkline. It is important that the students switch responsibilities so that all gain experience using the compass.
2. Find a large open concrete or blacktop surface on which to do the activity. If such an area is not available, have students use some other large area. They can mark the origin with a piece of paper or a rock and the trail with string anchored by pencils or rocks.

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3. *Trail Blazers* has two options, one that uses cardinal and intermediate directional headings (N, S, E, W, NE, NW, SE, SW) and the other that uses degree measures. Use the option that best suits the needs of the class.
4. *Lengths* is the term used in this activity to designate an arbitrary linear measure. It can mean meters, paces, foot lengths, 50 centimeters—any length you decide.
5. A sheet of *Compass Roses* has been included (in *Finding Your Way with a Compass)* for those classes using only the directional headings. Make a copy of this page on transparency film. Cut out each compass rose and use rolled transparent tape to attach it to the face of the compass. Be certain to align the N on the compass rose to the N on the bezel of the compass. (The directions appear backwards on the *Compass Roses* page so that when the transparency copy is properly attached to the compass, the print will not rub off with usage.)
6. Consult *Finding Your Way with a Compass* in order to teach the use of the compass.
7. At your discretion, you may wish to have students adjust their compasses for true north according to the declination at your location. Refer to *The Compass* for a U.S. declination map and directions on how to adjust the compass.

Procedure

Part 1

1. Ask students in what different ways people give directions to various places. [turn left, go three blocks, the first building on the right; take this street north for two blocks, turn east for two; second building on the right after the gas station; etc.] Ask them what kind of directions could be given if no streets or buildings are nearby. Bring them to the idea of using a compass to find locations.
2. Distribute the compasses and instruct students in their use (see *Finding Your Way with a Compass*). Emphasize the following three steps: turn the bezel until the directional heading (or degree) is over the white **line** under the bezel, turn your body until the "**red is in the shed**," and walk the way the **direction arrows** are pointing.
3. Give students *Some Quick Trips* and have them practice using their compasses.
4. Distribute the *Trail Blazers* page, explain the roles for the group members, describe the unit of *length,* and then go outside.
5. Have students follow directions marking their origins and trail with chalk. Distribute the *Answer Key* so that they can determine their accuracy.

Part 2

1. Invite students to plan a trail in which they determine and record the compass readings and the linear measures to go from an origin of their choice to a "treasure."
2. Have groups exchange their trails to see how accurately the directions can be followed.

Discussion

1. In your own words, what are the steps to using a compass?
2. Why is it important to hold the compass next to your body?
3. When would you use a compass?
4. If you were given another set of instructions, how could you be more accurate? [Answers will vary, but two suggestions are 1) select a distant landmark to help get straighter lines, 2) have two students use the compass; one makes sure the compass is oriented north while the other makes the directional sighting.]
5. Did you run into any troubles when you followed another group's directions to a treasure? Explain.

Extensions

1. Use chalk to mark a trail and have students make an accurate record of its path by using a compass and linear measuring device. They can then exchange papers so that others can check their accuracy.
2. In order for students to understand the necessity of accurate measurements, mark the origin and have one student walk 20 paces at 45° and another student walk 20 paces at 40°. Discuss the difference 5° makes in 20 paces and extend the discussion to what would happen if students were to walk 100 paces.
3. Plot an orienteering course that gives students clues to determine one "leg" of the trail at a time. At each stop, students will pick up the directions for the next "leg."

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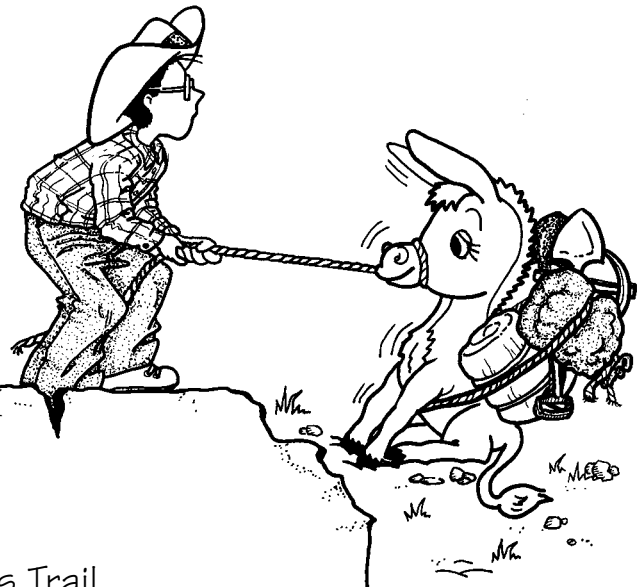
Trail Blazers



Design a trail for others to follow.

_____'s Trail

Origin:

Location of treasure:

Complete and cut out the answer key before giving the trail instructions to others.

Answer Key for _____'s Trail

Origin:

Location of Treasure:

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Plod and Plot

Topic
Plotting pictures using a directional compass

Focus
Students will use a compass and metric measuring tape to plot spots which they connect to make dot-to-dot "pictures."

Key Question
What dot-to-dot "pictures" can we make by using compass readings and distance measures?

Guiding Documents
Project 2061 Benchmarks

- *Without touching them, a magnet pulls on all things made of iron and either pushes or pulls on other magnets.*
- *Scale drawings show shapes and compare locations of things very different in size.*
- *Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.*

NRC Standards

- *Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.*
- *People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.*

*NCTM Standards 2000**

- *Describe location and movement using common language and geometric vocabulary*
- *Understand such attributes as length, area, weight, volume, and size of angle and select the appropriate type of unit for measuring each attribute*

Math
Measurement
    angle
    linear
Geometry

Science
Physical science
    magnetism
Earth science
    Earth's magnetic poles

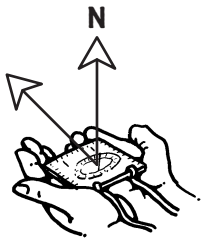
Integrated Processes
Observing
Comparing and contrasting
Collecting and recording data
Interpreting data

Materials
For each group:
    directional compass
    crepe paper streamers or yarn (see *Management 3*)
    6-meter tape measures (see *Management 6)*
    paper markers or flags (see *Management 5)*

For each student:
    1 360-degree protractor, included (see *Management 7)*
    metric ruler

Background Information
This activity is an application of angle measurement. A directional compass is a marvelous measurement tool that is divided into 360 degrees. The compass used for this investigation is simply a magnetized needle suspended on a pivot so the needle can spin freely. The needle will therefore align to the north and south because of the Earth's magnetic field.

A bearing is an angle, measured in degrees (sounds much like a protractor!) made with a line (actually a ray) heading north and a line (ray) heading toward a desired location. The compass bearer is the vertex of the two rays. Angles are always measured off the north line, or zero degrees, and are counted clockwise around the compass dial.



In protractor investigations, zero degrees is located at the baseline, 90 degrees forms a right angle, and 180 degrees forms a line. With the directional compass, zero degrees is still the baseline and indicates magnetic north. Ninety degrees forms a right angle with the baseline and indicates east. One hundred eighty degrees forms

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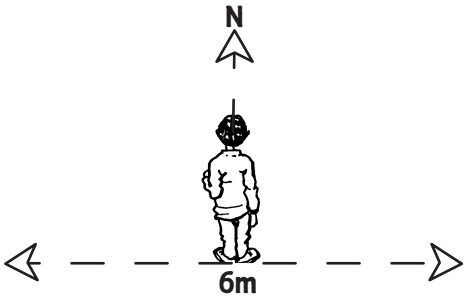
a line and indicates south. Students may be amazed to see that the unit of degrees continues around the compass to form a complete circle with 270 degrees representing west and 360 degrees being the same as zero, or north.

A circular protractor has been included in this activity so that students may apply the exploration with the directional compass to a two-dimensional representation on paper. This part should help them to more fully understand the connection between the directional compass and the protractor.

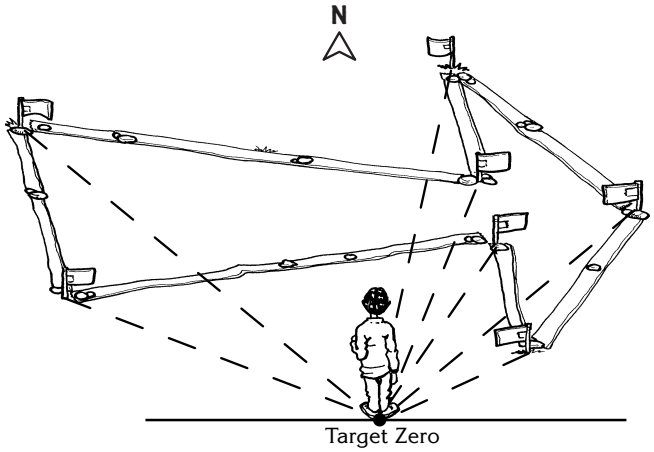
For your information: The magnetic poles are not the same as the geographic poles. As a matter of fact, the magnetic poles move constantly. Because of this discrepancy, called declination, navigators and geologists, to name a few, must make adjustments to their instruments. This investigation, however, requires no adjustments as the directional compass is being used as an application to angle measurement.

Management

1. Be certain that students know how to use the directional compass (see *Finding Your Way with a Compass)*.
2. Divide the class into groups of four to six members. Students should alternate roles within their groups. The necessary roles are: Compass Bearer, 2 Measurers, and a Reporter/Plotter/Verifier.
3. It is easiest if each group is given a small roll of crepe paper streamer. If this is not possible, have groups share. The crepe paper can be torn so that scissors do not need to be transported outdoors. If crepe paper is not available, brightly colored yarn can be substituted.
4. Each group will need a six meter by six meter area. Playground areas, basketball courts, parking lots, etc. work nicely. Mark off the areas with bits of paper. If it is windy, use pebbles to secure the paper. Orient the areas to face north since all measurement will take place from the center of a baseline which extends east and west. No measurements will be taken to the south.



5. As students "plod and plot" each of the bearings, they will need to mark and label the points so that when they are finished, the points can be connected in dot-to-dot fashion to form a picture. Markers can be scraps of paper which are weighted with rocks or paper flags taped to pencils which are stuck in the ground. Each group will need to label their markers (e.g., A-1, A-2, A-3, etc.).



6. The meter tapes have been marked in decimeter units to correlate with the decimal values on the distance scales. Each group will need six assembled tapes. Copy these on six different colors so that each meter is distinctive and easy to count.
7. Copy the 360-degree protractors on transparencies. Each student will need a protractor. *Part Two* is best introduced by demonstrating the procedure on the overhead projector.
8. Picture A is a house, B an arrow, C a tree, D a five-pointed star, and E is an umbrella.

Procedure

Part One

1. Review using directional compasses.
2. Ask, *What dot-to-dot "pictures" can we make by using compass readings and distance measures?*
3. Inform the students that they will be going outdoors to plot their pictures.
4. Form groups. Have each group construct and tape together six meter tapes. Assign a picture to each group (A, B, C, D, or E.) Distribute crepe paper, paper for flags, and picture directions. To eliminate confusion over which scale to use for the linear measure, show the students how to fold the column labeled *Mini-Distance* back out of the way. Make the fold line from the circle at the top right of the page to the circle at the bottom right of the page. The *Distance* column will be used outdoors.
5. Take the students outdoors.
6. Go over the procedure with the students:
   - Elaborate on how the compass bearer, standing at Target Zero (center of the baseline, facing north), should turn the bezel of the compass to the specified bearing and then turn his or her body until "the red is in the shed."

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At this point, tell the compass bearer to remain at Target Zero, look up, and find an object or location that is in that direction.

- Inform them that two measurers will then measure from Target Zero the distance given on the picture directions for that bearing. It is the task of the compass bearer to make certain that the measurers are aligned with the bearing.
- Tell them that another group member will mark the measured point with a labeled scrap of paper or flag.
- Encourage them to have a group member verify that the point is in the direction of the bearing.

7. Emphasize that all measurements, angle and linear, will be made from the Target Zero spot. Advise the students to mark the spot so that they will be consistent in its use.
8. Send groups to their respective sites. Have them plot and mark each point.
9. When all points have been marked, direct the students to sequentially connect the points with a continuous streamer of crepe paper.
10. Have them record what "picture" they made on their direction sheet.
11. Allow time for the viewing of all "pictures."

Part Two

1. Inform students that they will now make mini-dot-to-dot pictures. Distribute the 360-degree protractors and ask how they are like the directional compasses.
2. Tell the students that they will be illustrating one of the dot-to-dot pictures that was made outdoors. Allow them to choose any of the five.
3. Use the overhead projector to demonstrate the procedure for making the mini-dot-to-dots. Direct the students to put the crossmark of the protractor on the Target Zero. Zero degrees on the protractor should be oriented to the north. Inform them that all readings will be taken from this position.
   Demonstrate these two examples:
   - 350 degrees, 8.5 cm (First mark the bearing and then use a ruler to measure the distance of 8.5 cm from Target Zero along that bearing. Make a point. Label it 1.)
   - 25 degrees, 2.7 cm (Mark the bearing. Because of the size of the protractor, the mark will be beyond the length of the distance measure. Emphasize that students can lightly draw a line to the marked bearing and then measure 2.7 cm from the Target Zero and make their point. The entire line can then be erased. Label this point 2.)
4. To eliminate confusion over which scale to use for the linear measure, show the students how to fold the column labeled *Mini-Distance* over the *Distance* scale that was used outdoors. Tell them to fold the right top circle over the left top circle of the page and the bottom right circle over the bottom left circle.
5. Allow students to make their mini-dot-to-dot pictures, connecting the points in sequence.
6. Challenge them to draw a simple illustration that can be transformed into a dot-to-dot picture. Have them determine the bearing and linear distance from Target Zero for each point. Once finished, allow time for the students to trade pictures and check each others work.

Discussion

1. What was the hardest part about making the dot-to dot pictures outdoors. (perhaps staying on the bearing)
2. The southern half of the compass was never used. Why? [Everything was oriented to the northern half of the compass. The baseline served as a division line between the north and south. No pictures extended past the baseline.]
3. How is the compass like the protractor? [Both have 360 degrees. They are both marked in one-degree units. They both form circles.]
4. For each point that you marked, what readings did you have to know? [compass/protractor bearing and distance measure]
5. Why was it necessary to connect the points in sequence? What would have happened if you hadn't?
6. Were you able to detect any mistakes in your plotted points? How? [When we connected the points, the picture was wrong.]
7. How did you fix the mistakes? [Went back to Target Zero and checked the bearing and distance mesaures for those points.]

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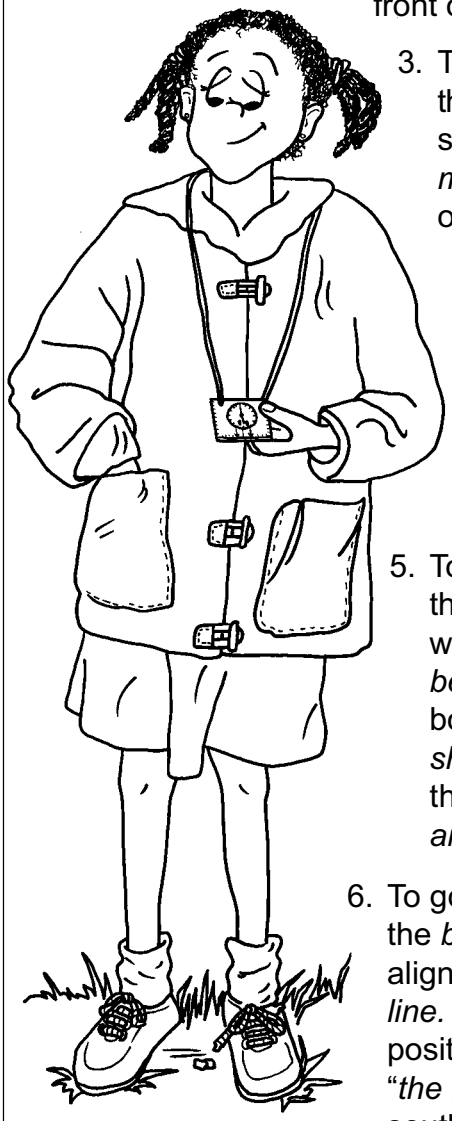
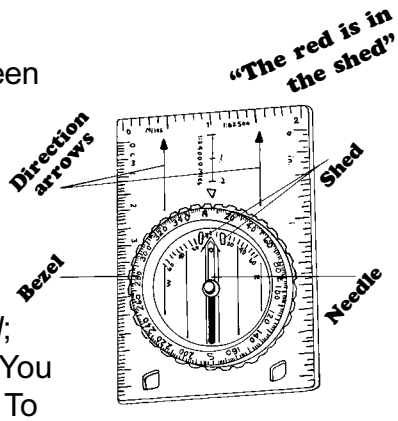
Finding Your Way with a COMPASS

1. To wear the compass around your neck, thread a meter-long string through the holes in the compass and tie the ends together.

2. Hold the compass with the hole-end next to your body and the *direction arrows* pointing straight in front of you.

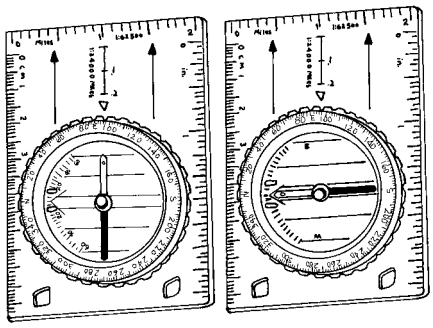


3. Turn the *bezel* so that the *shed* is between the two *direction arrows*. The N (0°) should be over the small white *marker line.* The *marker line* is found on the black rim of the compass.

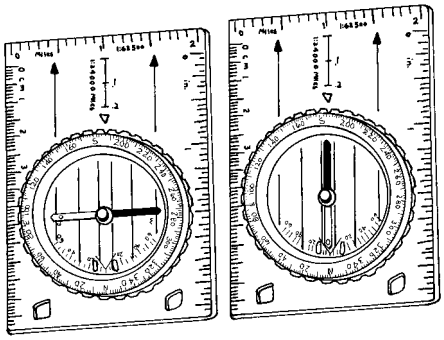


4. Turn your body until the red end of the *needle* is in the *shed*; hence, "*the red is in the shed*." You are now facing magnetic north. To head north, walk in the direction the *direction arrows* are pointing. Make sure the compass is held next to your body.

5. To go east, stay in place and turn the *bezel* until the E (90°) is aligned with the white *marker line.* Leaving the *bezel* in this position, turn your body until "*the red is in the shed*." To head east, walk in the direction the *direction arrows* are pointing.



6. To go south, stay in place and turn the *bezel* until the S (180°) is aligned with the white *marker line.* Leaving the *bezel* in this position, turn your body until "*the red is in the shed*." To head south, walk in the direction the *direction arrows* are pointing.



7. To go northwest, stay in place and turn the *bezel* until NW (315°) is aligned with the white *marker line.* Leaving the *bezel* in this position, turn your body until "*the red is in the shed*." To head northwest, walk in the direction the *direction arrows* are pointing.

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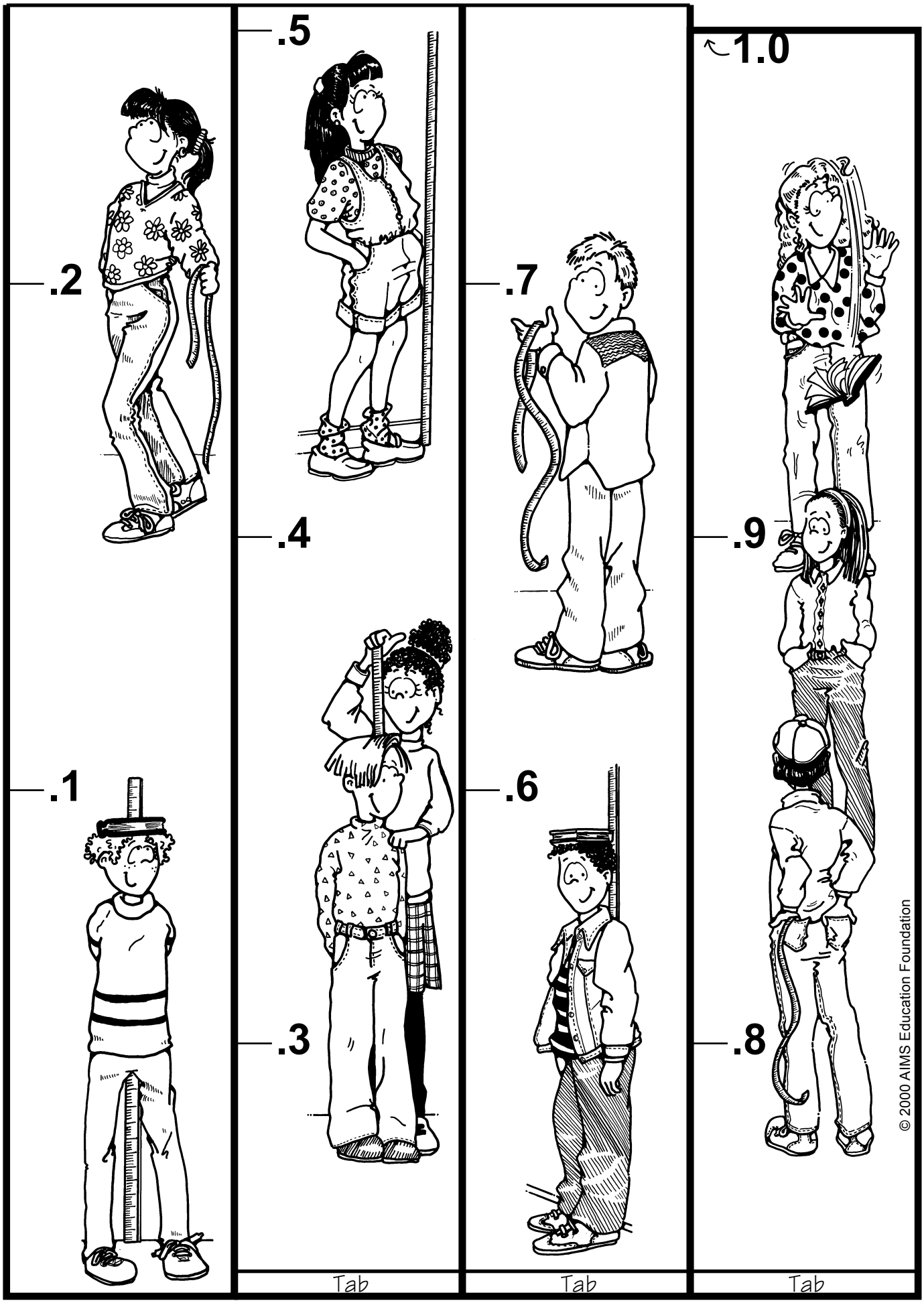

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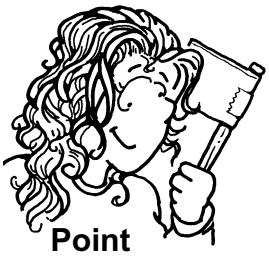
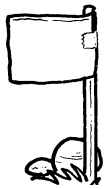


Plod and Plot

PICTURE DIRECTIONS

Point	Bearing (degrees)	Distance (meters)	Mini-Distance (cm)
A-1	270	3.0	5.0
A-2	323	5.1	8.5
A-3	320	5.6	9.3
A-4	0	5.7	9.5
A-5	40	5.6	9.3
A-6	37	5.1	8.5
A-7	90	3.0	5.0
A-8	270	3.0	5.0

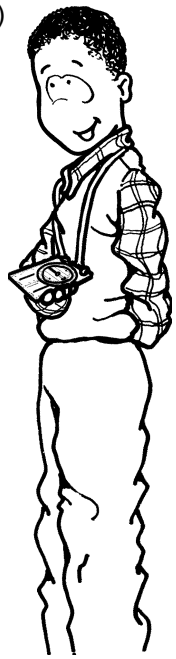


Picture: _____

Point	Bearing (degrees)	Distance (meters)	Mini-Distance (cm)
B-1	300	3.0	5.1
B-2	325	4.6	7.7
B-3	26	3.4	5.7
B-4	18	4.9	8.1
B-5	47	4.0	6.6
B-6	62	1.7	2.9
B-7	33	2.8	4.7
B-8	300	3.0	5.1

Picture: _____

Point	Bearing (degrees)	Distance (meters)	Mini-Distance (cm)
C-1	270	0.5	0.8
C-2	322	1.1	1.9
C-3	284	2.5	4.2
C-4	333	2.5	4.2
C-5	322	2.9	4.8
C-6	352	4.0	6.4
C-7	343	4.0	6.5
C-8	0	5.2	8.6
C-9	17	4.0	6.5
C-10	8	4.0	6.4
C-11	38	2.9	4.8
C-12	27	2.5	4.2
C-13	76	2.5	4.2
C-14	38	1.1	1.9
C-15	90	0.5	0.8
C-16	0	0.0	0.0



Picture: _____

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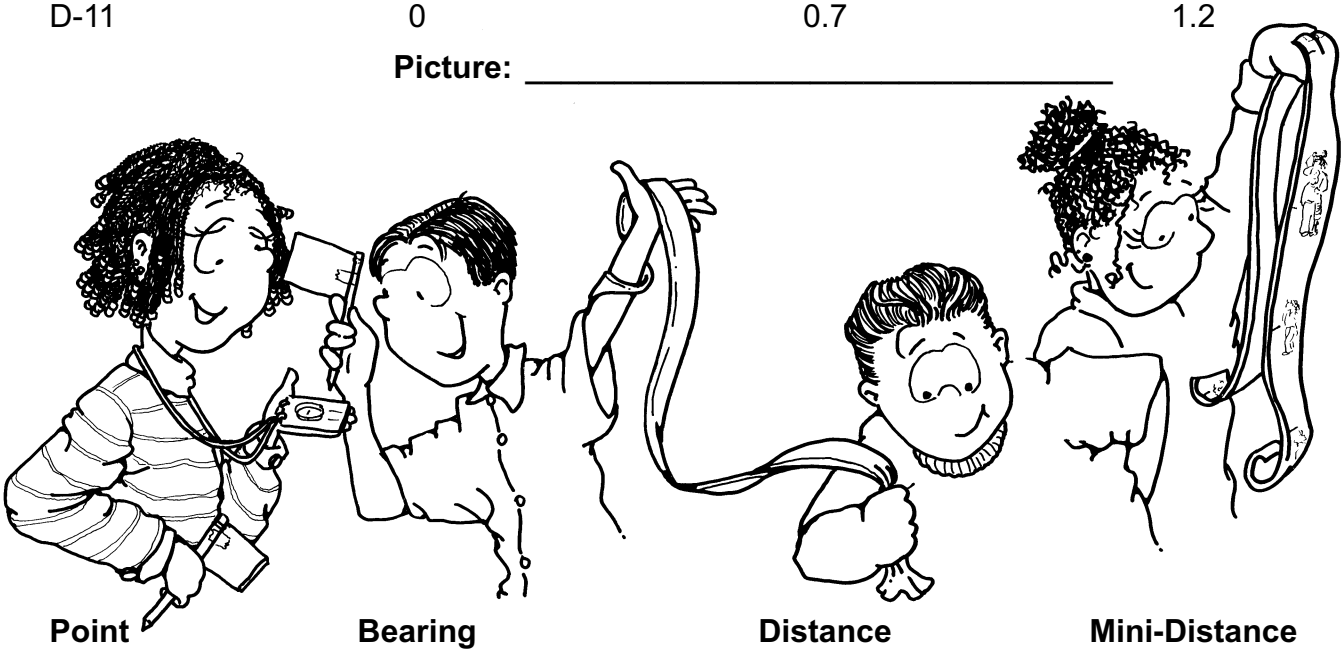
Plod and Plot

PICTURE DIRECTIONS

Point	Bearing (degrees)	Distance (meters)	Mini-Distance (cm)
D-1	0	0.7	1.2
D-2	270	1.7	2.8
D-3	323	2.3	3.8
D-4	320	4.1	6.8
D-5	345	3.4	5.7
D-6	0	4.7	8.1
D-7	15	3.4	5.7
D-8	40	4.1	6.8
D-9	37	2.3	3.8
D-10	90	1.7	2.8
D-11	0	0.7	1.2

Picture: _____



Point	Bearing (degrees)	Distance (meters)	Mini-Distance (cm)
E-1	296	0.7	1.1
E-2	322	0.7	1.2
E-3	339	0.4	0.7
E-4	10	2.2	3.7
E-5	347	1.8	3.0
E-6	344	2.6	4.4
E-7	327	2.9	4.8
E-8	12	5.6	9.3
E-9	56	2.9	4.8
E-10	38	2.8	4.6
E-11	35	2.0	3.4
E-12	17	2.3	3.8
E-13	0	0.0	0.0

Picture: _____

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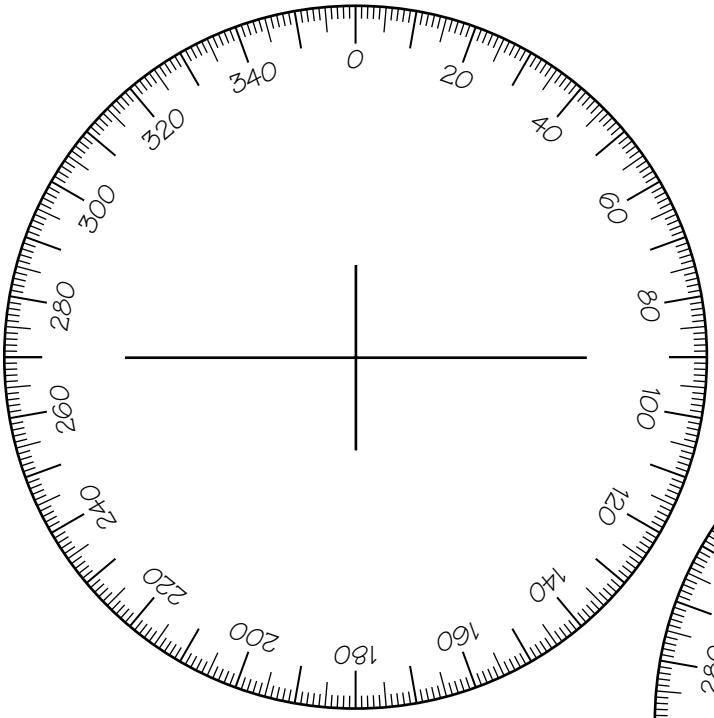
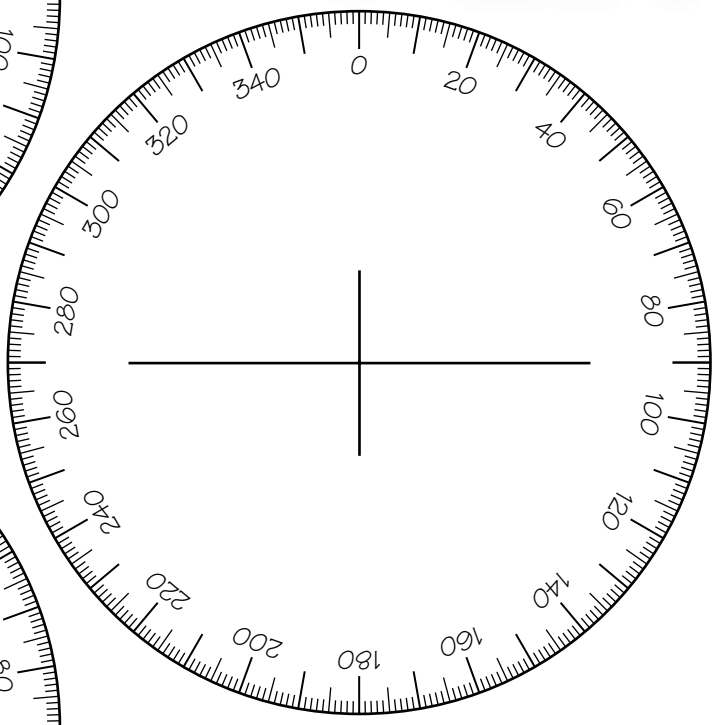
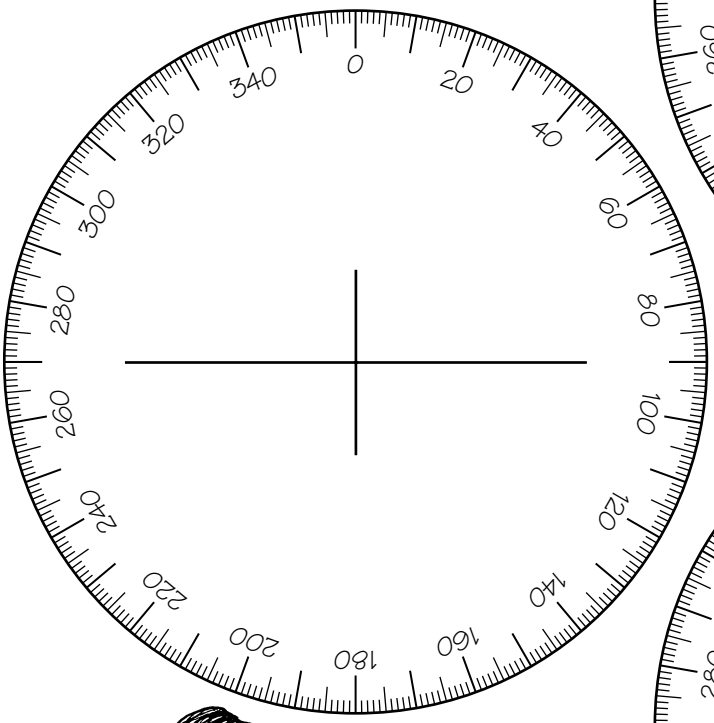
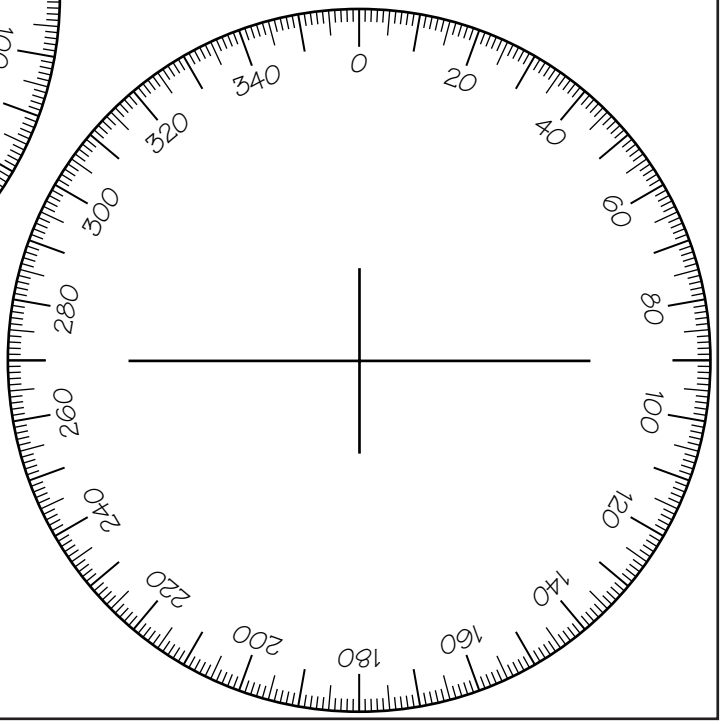
PLOD AND PLOT

360° Protractor









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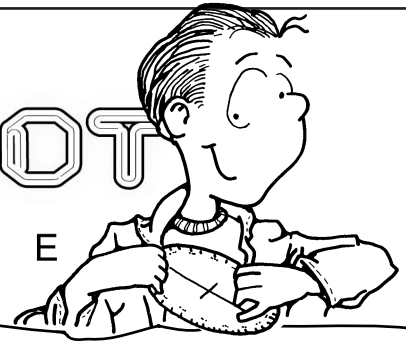
PLOD AND PLOT



Circle the dot-to-dot picture you choose to illustrate.

A B C D E

Draw a simple dot-to-dot picture.

Determine the compass bearing and distance measure for each point. Write these on another paper.

N

Target Zero

N

Target Zero

Picture:

Trade papers with a classmate and check each other's work.

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Scale the Room

Topic
Scale drawing

Key Question
How can we fit this room onto a piece of paper?

Focus
Students will record room measurements on a sketch map, then draw a map of the room to scale.

Guiding Documents
National Geography Standards
- *Draw sketch maps to illustrate geographic information*
- *Create maps that are labeled appropriately (e.g., use a self-checking system such as TODALSIGs—Title, Orientation, Date, Author, Legend, Scale, Index, Grid, source)*

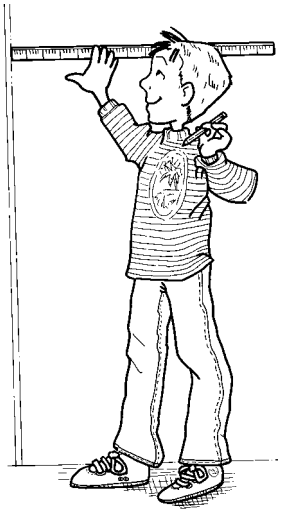
Project 2061 Benchmarks
- *Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.*
- *Scale drawings show shapes and compare locations of things very different in size.*

NCTM Standards
- *Understand and apply ratios, proportions, and percents in a wide variety of situations*
- *Estimate, make, and use measurements to describe and compare phenomena*

Social Science
Geography

Math
Estimation
Measurement
  length
Whole number operations
Proportional reasoning
Spatial sense

Integrated Processes
Observing
Collecting and recording data
Comparing and contrasting
Interpreting data
Making maps



Materials
Meter sticks
Metric rulers
Calculators

Background Information
Imagine a map of your school grounds that is the actual size of your school grounds. Not only would it waste a lot a paper, but it would be hard to carry and store. It would be even harder to read because the map would be too big to see all at one time. That's why many professions, from architecture to engineering, use scale drawings. Scale drawings represent areas or objects much too large to draw their actual size.

As students prepare to draw a room to scale, they should start with the perimeter, as well as objects in it such as doors and windows. Then the pieces of furniture that are to be included should be identified. A sketch map, drawn freehand with only a rough idea of relative size, is a productive way to gather and record information.

The National Geographic Society uses the following scale format: first a ratio (1:50), followed by units of measurement (1 cm = 50 cm). When scaling a non-standard unit such as walking steps to a standard unit, the first ratio is omitted; the scale would be expressed as 1 cm = 5 steps.

Management
1. Choose the room to be drawn to scale. The classroom has obvious advantages but, if the amount of furniture seems too much to handle, identify a few specific items with which students are to work. Another option is to just draw the perimeter of the room, identifying the position and width of the windows and doors.
2. Groups of three or four work well. Job titles might include recorder (records items and measurements), checker (keeps group on task, verifies accuracy), and workers (take measurements and perform computations).
3. Consider giving each group a section of the room to map and combine these into one map or have each group map the entire room.
4. Round measurements to the nearest decimeter, recording them either as centimeters (190 cm) or as tenths of a meter (1.9 m).

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5. To figure the scale, develop a ratio between the room length and the graph paper squares.

   If the room length is 976 centimeters and you are using the 23 cm-long grid in this activity, a good ratio might be 1:50 or 1 centimeter = 50 centimeters or 1 millimeter = 5 centimeters.

   How was this figure determined? If 976 is divided by 23, the result is 42.43. In this case, every centimeter on the grid needs to represent at least 43 actual centimeters. Since it is easier to work with numbers divisible by 5 and 10, a scale of 1 cm = 50 cm is a good choice.
6. Square floor tiles can also be used as a measuring standard with each tile representing one graph paper square. Glue graph paper together, if needed, to get the dimensions of the room.

(The following is provided for those students prepared for more independent investigations.)

Open-ended: Ask the *Key Question* and challenge student groups to organize and produce the final product.

Procedure

1. Ask the *Key Question*. Tell students they will have a chance to create their own room map — to scale. Discuss which items should be represented on the map, perhaps listing them on a large chart.
2. Explain that students will make a simple sketch map of the room, drawn freehand. On it, they will record measurements as well as the position of objects in relationship to each other. Distribute the sketch map page and measuring tools.
3. Have each group measure the length and width of the chosen items and record them on the sketch map.
4. Agree upon the scale to be used.
5. Instruct students to calculate scale measurements and record them in parentheses on the sketch map.
6. Give students the grid and have them construct a scale drawing of the room, starting with the perimeter.
7. Discuss and compare the results.

Discussion

1. What items should be included on our map?
2. Why make a sketch map first? [To show the general positions of objects and record measurements.] How accurate should our sketch maps be? [Sketch maps are quick, casual drawings. They are not meant to accurately show the scale of the room.]
3. What was easiest about this project? What was most difficult?
4. How can a scale drawing be useful? [planning where to place furniture or where to plant flowers and trees, building a house, comparing the sizes of states in the United States, calculating distances on a road map, etc.]
5. What professions use scale drawings? [cartographers, architects, contractors, landscapers, automobile engineers, etc.]

Extensions

1. Have each student draw a room in their house to scale.
2. Select an object from a period of history being studied, research its dimensions, and have students draw it to scale. Examples: Mayflower, Statue of Liberty, Egyptian pyramid, Acropolis.
3. Give students a scale map of a living room and some scaled furniture pieces. Challenge them to arrange the furniture with a conversation area and convenient pathways.

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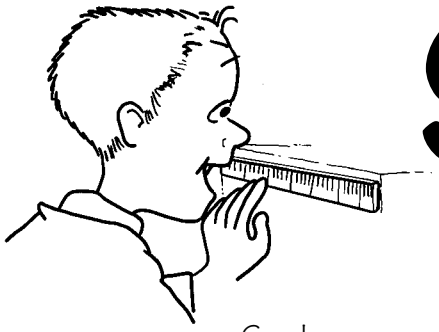
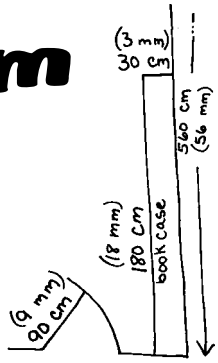


Scale the Room

Record room measurements on a sketch map, with scale measurements in parentheses. Draw the room to scale.



Scale:

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Scale the Room

Scale:

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Rallying Around

Topic
U.S. road map

Key Question
You have been chosen to participate in a "See America Road Rally." You will choose, at random, five cities to visit. After choosing your five cities, how long do you think your trip will take?

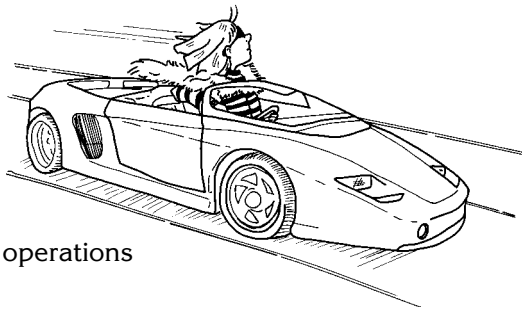
Focus
Students will use a U.S. road map to measure and compare distances between five randomly-selected cities while participating in a road rally simulation.

Guiding Documents
National Geography Standards
- *Interpret maps to make decisions*
- *Measure the distance between two locations in miles, kilometers, time, cost, and perception, and draw conclusions about different ways of measuring distance*

Project 2061 Benchmarks
- *In making decisions, it helps to take time to consider the benefits and drawbacks of alternatives.*
- *Measurements are always likely to give slightly different numbers, even if what is being measured stays the same.*
- *Estimate distances and travel times from maps and the actual size of objects from scale drawings.*

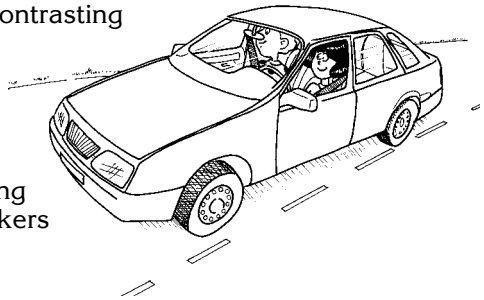
NCTM Standards
- *Estimate, make, and use measurements to describe and compare phenomena*
- *Compute with whole numbers, fractions, decimals, integers, and rational numbers*

Social Science
Geography



Math
Spatial sense
Estimation
Measurement
  length
Whole number operations
Ratios
Decimals

Integrated Processes
Predicting
Observing
Reading maps
Collecting and recording data
Comparing and contrasting
Interpreting data
Applying



Materials
For each group:
2 meters of string
crayons or markers
rulers
calculators
U.S. road map

Background Information
This road rally simulation is intended to spark student interest while strengthening skills such as reading a road map, identifying the most direct route between two places, and using a scale of miles. Students are also asked to locate and label selected cities and to identify states.

During the rally, students must use a constant average speed of 55 mph (or speed limit of your choice), but reality dictates that road conditions, traffic, weather, and other factors might affect travel speed. The speed variable is controlled to ensure fair comparisons between groups. Miles, rather than kilometers, are used because mileage information is more commonly available. Most road maps have kilometer scales which can be used, if you wish, along with a kilometer speed limit. The *Mileage Chart* would not be applicable.

To find the distance traveled by measuring with string, it is simplest to calculate the number of miles per centimeter. This figure can be multiplied by the measured string length to obtain the actual distance. Another way would be to construct a longer version of the map's scale distance and lay the string along it.

Management
1. Divide the class into groups of four or five.
2. Decide the number of hours which may be driven each day. Five- or ten-hour driving limits result in easier calculations for younger students. The mathematics is more challenging with six- or eight-hour limits.
3. To prepare the string, put tape around one end to mark the beginning of the group's measurements. As students reach each city, they will make a mark on the string. Their string measurements will be approximate.

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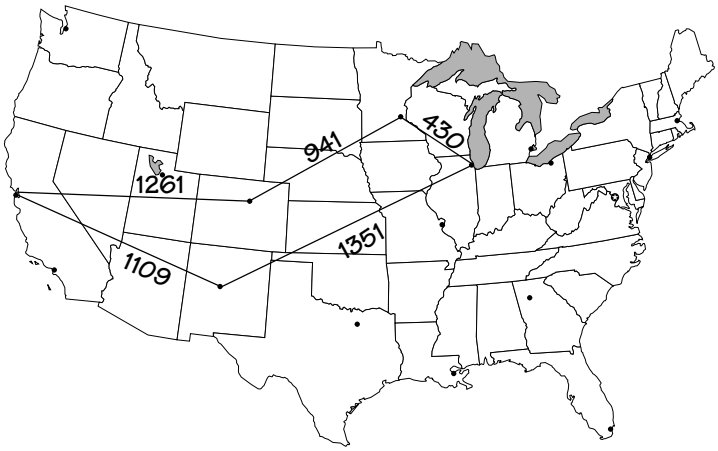
Procedure

1. Announce that the class is going to participate in a road rally. The challenge is to travel to five different cities and return home in the shortest amount of time. There will be rules everyone must follow.
2. Give each group the city names page and review the directions, starting at the bottom of the page. Have students cut out the names, lay them face down, and mix them up. Five names should be drawn, indicating the cities through which they will travel on their road rally.
3. Distribute the map page. Have students label the five cities on the map. On the bottom of the page, they should decide and record the order in which the cities will be visited, starting and ending with the city closest to their hometown.
4. Have students record the speed limit and daily driving time limit you or they have chosen. Remind students they must stop driving for the day when they reach one of their five cities even if they haven't driven the daily time limit.
5. Ask, "How many days do you think your trip will take?" Have each group record their estimate at the top of the page.
6. Give each group a United States road map. Instruct them to use the map scale to carefully estimate and record the number of miles equivalent to one centimeter.
7. Direct students to plan the roads they will travel and write the road numbers in the second column.
8. Tell students to place the string along the contours of each road and measure the distance between each city to the nearest tenth of a centimeter. Record as a decimal. Students must return to their city of origin to complete the rally.
9. Have students figure the actual travel distance. One method is to multiply the number of centimeters of string it took to complete the trip times the number of miles in one centimeter.
10. On the blank map, have students draw straight lines between the cities to show their route and write the actual distances on the lines.



11. Have students use the time formula to calculate hours, rounding decimals to the nearest tenth. They should then calculate the number of days used according to the rules.
12. Instruct students to compute the total distance and total time. If there is a tie between two or more groups for the least number of days, look at the hour totals.
13. As part of a concluding discussion, have each group compare their distances and times with the *Mileage Chart*.

Discussion

1. How did you decide the order in which to visit your five cities? (In most cases, the best strategy is to find the shortest and, therefore, most efficient route.)
2. What kinds of problems did you have deciding the most direct route? How did you solve these problems?
3. What different regions did you visit?
4. Through how many states did your rally take you? Name them.
5. What was the shortest leg of your trip? ...the longest leg?
6. How long did your rally take?
7. How does your route and time compare with other groups traveling to some or all of the same cities?
8. What did you like best about the road rally?

Extensions

1. Repeat the activity using "as the crow flies" distances.
2. Obtain an airline schedule. Compare driving time to flight time. Should you include the wait at the airport?
3. Determine which two cities are farthest apart.
4. Pin one road map to a bulletin board. Using different color yarn, trace each group's trip. Pin paper markers showing the order. Paper cars can be placed at the city of origin.
5. Make a graph which compares the groups' distances and times.
6. Discuss how time zones affect traveling.

Curriculum Correlation

Language Arts

Research the cities visited to learn about founding date, points of interest, etc. Design a travel brochure.

Art

1. Draw road signs that might have been seen along the way.
2. Design a poster advertising the "See America Road Rally".

Technology

Use the "Travel Agent" option in the computer program, *Survival Math*, from Sunburst Communications, Inc.

Home Link

Encourage students to be a road map navigator on the next family trip.

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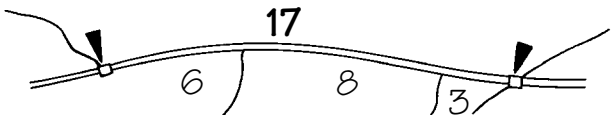
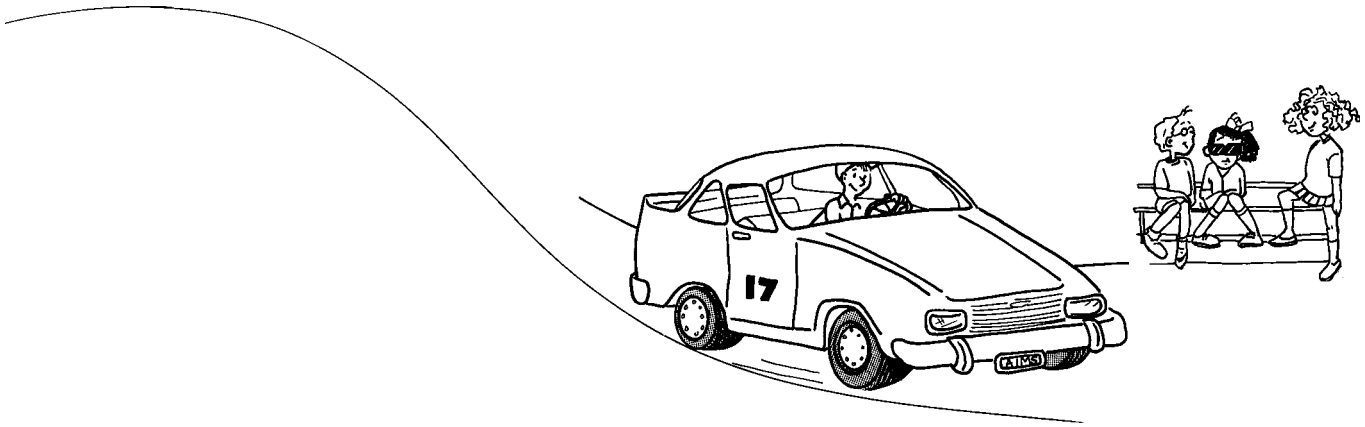
As an alternative to using string to measure the distance traveled, you may wish to have students total the distances listed in red or black along a road on the map. One can use either the cumulative miles shown between arrows or the more numerous listings of miles between road intersections. To identify the two kinds of distances, consult the legend on your road map. Using this method gives students practical experience with a convenient and useful feature road maps provide.



If you choose to use this alternative, customize the map activity sheet by superimposing the following table over the current table on your copy master before making copies for your class.

Distance		Time	
		Hours	Days
Leg 1			
Leg 2			
Leg 3			
Leg 4			
Leg 5			
Total		Total	



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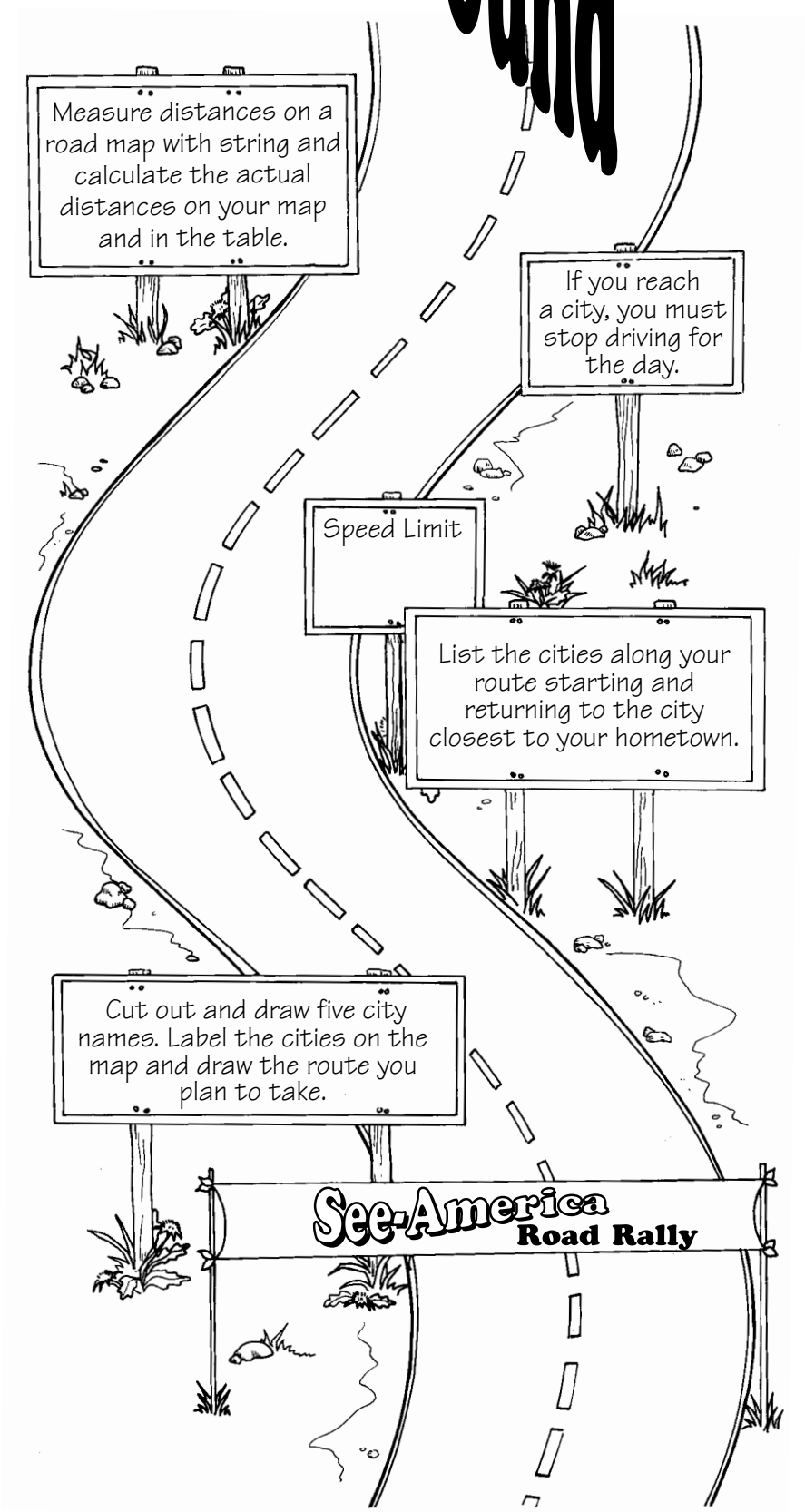
Rallying Around



Albuquerque
Atlanta
Boston
Chicago
Cleveland
Dallas
Denver
Detroit
Los Angeles
Miami
Minneapolis
New Orleans
New York City
St. Louis
Salt Lake City
San Francisco
Seattle
Washington D.C.

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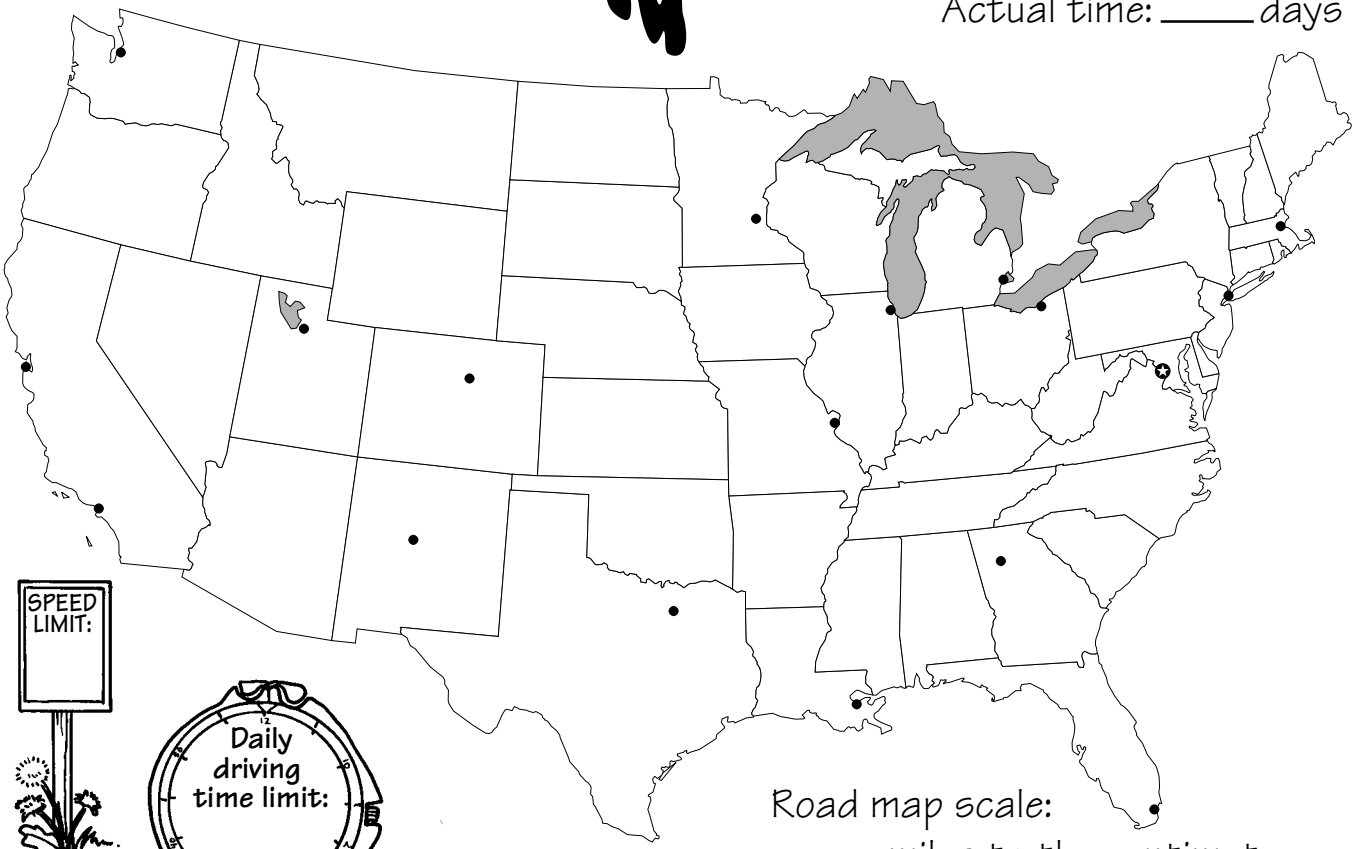
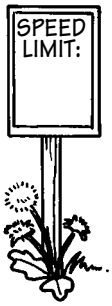
Rallying Around

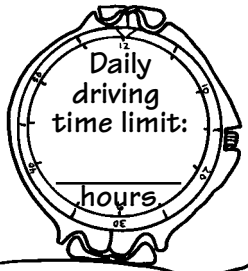
Start and return to the city closest to your hometown.

Estimated time: _____ days

Actual time: _____ days







Road map scale:
_____ miles to the centimeter

Cities	Roads traveled
1. _____	
2. _____	> _____
3. _____	> _____
4. _____	> _____
5. _____	> _____
6. _____	> _____

Time = $\frac{\text{Distance}}{\text{Speed limit}}$

Distance		Time	
String	Actual	Hours	Days
Total		Total	

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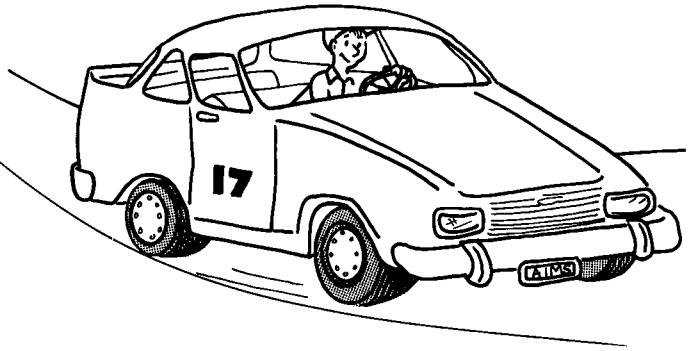
Rallying Around

MILEAGE CHART



1424 28:31	Number of miles Drive time

These distances and driving times represent the most favorable commonly traveled routes under normal conditions. Driving times are average times within posted speed limits, excluding stops.

	Albuquerque	Atlanta	Boston	Chicago	Cleveland	Dallas	Denver	Detroit	Los Angeles	Miami	Minneapolis	New Orleans	New York City	St. Louis	Salt Lake City	San Francisco	Seattle	Washington, DC
Albuquerque		1424 28:31	2248 43:56	1351 26:44	1616 31:27	670 13:11	449 8:46	1572 31:08	820 15:51	2018 39:00	1251 24:47	1188 23:25	2029 39:31	1051 20:26	617 12:00	1109 21:38	1460 29:30	1896 37:68
Atlanta			1115 22:00	722 14:03	734 14:32	815 16:11	1442 28:06	735 14:43	2244 44:22	688 12:49	1152 22:15	488 9:44	896 17:35	598 11:42	1949 38:45	2533 50:09	2793 53:04	672 12:47
Boston				1009 19:27	654 12:31	1795 35:28	2016 38:57	832 16:10	3082 60:07	1571 31:12	1439 27:39	1578 31:05	219 4:25	1197 23:30	2420 46:22	3174 61:20	3123 59:27	443 9:13
Chicago					355 6:56	933 18:58	1047 20:12	287 5:34	2113 41:22	1410 26:52	430 8:12	983 19:20	831 16:17	300 6:18	1451 27:37	2205 42:35	2114 40:00	753 15:29
Cleveland						1198 23:41	1362 26:26	178 3:39	2428 47:36	1342 27:04	785 15:08	1092 21:15	476 9:21	565 11:01	1766 33:51	2520 48:49	2469 46:56	398 8:33
Dallas							806 16:05	1154 23:22	1425 27:56	1348 25:49	1013 19:49	518 10:14	1576 31:03	633 12:40	1287 25:11	1779 34:49	2130 42:41	1352 26:15
Denver								1334 25:46	1066 27:10	2130 40:55	941 18:00	1324 26:19	1822 35:29	844 16:24	507 10:39	1261 25:37	1350 28:09	1689 33:09
Detroit									2400 46:56	1423 27:32	717 13:46	1093 21:26	654 13:00	521 10:42	1738 33:11	2492 48:09	2401 45:34	576 12:12
Los Angeles										2773 53:45	2007 39:10	1906 37:42	2849 55:22	1871 37:11	721 14:00	425 8:29	1174 22:51	2716 52:59
Miami											1840 35:04	900 16:54	1352 26:47	1286 24:31	2637 51:34	3127 60:38	3481 65:53	1128 21:59
Minneapolis												1223 25:02	1261 24:29	540 12:00	1267 25:30	2021 40:28	1684 31:48	1183 23:41
New Orleans													1359 26:40	683 13:02	1805 35:25	2297 45:03	2648 52:55	1160 22:31
New York City														978 19:05	2242 43:12	2996 58:10	2945 56:17	224 4:48
St. Louis															1351 27:03	2105 42:01	2195 41:22	845 16:42
Salt Lake City																754 14:58	843 17:30	2168 41:50
San Francisco																	852 16:15	2922 56:48
Seattle																		2867 55:29
Washington, DC																		

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Handy Maps

Topic
Topographical maps

Key Question
What do the lines on a topographical map tell us?

Focus
Students will draw contour lines, lines that connect points of equal elevation, on their fists to help understand the lines on a topographical map.

Guiding Documents
Project 2061 Benchmarks

- *Geometric figures, number sentences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.*

NCTM Standards

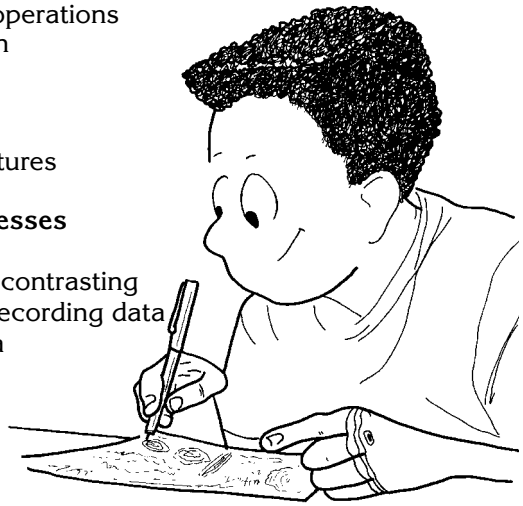
- *Relate physical materials, pictures, and diagrams to mathematical ideas*
- *Use mathematics in other curriculum areas*
- *Make and use measurements in problems and everyday situations*

Math
Measuring
Whole number operations
multiplication

Science
Earth science
mapping features

Integrated Processes
Observing
Comparing and contrasting
Collecting and recording data
Interpreting data

Materials
Plastic wrap
Felt-tip markers
Centicubes
Tape



Background Information

Students are often familiar with maps that show two horizontal dimensions, but geologists, as well as other map users, often require information about the third dimension of elevation. *Topographical maps* are two-dimensional representations of a three-dimensional Earth. Topographical maps use contour lines to represent the elevations of various features. A *contour line* is a line that connects areas of the same elevation above sea level.

In this activity students are going to make topographical maps of their hands. By drawing the contour lines and looking down upon their hands, they should begin to understand that the lines connect points of like elevation and can be used to tell which areas are highest, lowest, steepest, etc.

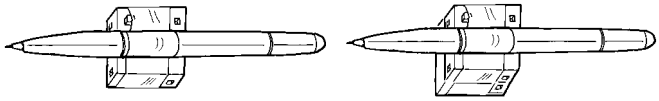
When teaching students about topographical maps, some important observations are:

- widely spaced lines represent gentle slopes
- closely spaced lines represent steep slopes
- evenly spaced lines represent slopes that are uniform
- all contour lines would eventually close if a map were large enough
- contour lines rarely cross each other

The *contour interval* is the vertical distance between adjacent contour lines. In this activity, the contour interval on the students' fists will be approximately one centimeter, the height of a centicube.

Management

1. Students should work in pairs. One student from each pair will wrap his/her left fist in plastic wrap so that the other student in the pair can draw contour lines on the wrap.
2. Test the felt-tip markers to make certain they will mark on the plastic wrap.
3. The contour interval will be considered one centimeter even though the marker tip actually sits higher than the centicube. After the first contour line is drawn, all other lines will be drawn one centimeter higher than the preceding line.
4. Three by three by one platforms of centicubes will be used for resting the markers. To increase the height for the adjacent contour line, another three x three x one platform will be added to the first. Tape the marker to the first platform and add the other platforms to the bottom as necessary.



5. Tear off at least one piece of plastic wrap (30-40 cm long) for each pair of students. Other pieces may be needed until students learn the procedure.
6. Gather some pictures of topographical maps from encyclopedias, science/geography texts, the U.S. Geological Survey, hiking groups, etc.
7. Some discussion of the term *contour interval* may be necessary. It should be defined as the distance between contour lines. When students determine the contour intervals on the bottom of their activity sheet, they may be referred to as the *rule* for determining the distance between the contour lines.

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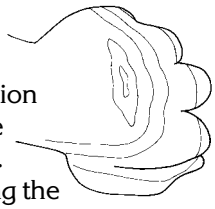
Procedure

1. Show the students some topographical maps. Ask the *Key Question*. Inform students that to understand the lines on the map, they will be making similar maps of their fists. Distribute plastic wrap, tape, felt-tip markers, and centicube platforms to each student pair.
2. Direct one student in each pair to place the plastic wrap on the back of their left hand. Demonstrate how to pull the ends of the plastic wrap to the palm-side and to hold it in a fist. (If necessary, tape can be used to help anchor the plastic wrap.) Point out that the other student in the pair will be drawing a topographical map on this plastic wrap.
3. Show students how to rest the felt-tip markers on the centicube platform. Have them tape their markers to the first platform and draw the first line. Wait while they do this. Ask them what they know about this line. [It shows the height of one centimeter on our fists.]
4. Urge them to add a second centicube platform to their marker rests and draw another line around the fists. Ask them what they know about this line. [It is two centimeters high. It is one centimeter higher than the first line drawn.]
5. Encourage them to continue adding centicube platforms and drawing lines until no more lines can be drawn. Have them leave their fists wrapped in the plastic wrap for *Discussion*.
6. Distribute the activity sheet and have students illustrate the contour lines of their fists. When the illustration is completed, students may remove the plastic wrap and finish the page. Emphasize the importance of knowing the contour interval for each of the mountains pictured.



Discussion

1. How high was your fist?
2. Were you able to draw a line at the highest point of your fist? Explain. [Probably not, the highest point was higher than the last line drawn but not high enough for another line.]
3. With that information, can you tell me exactly how high your fist is? [No, but it is higher than _____ cm, but less than _____ cm.]
4. Find someone with a fist that is taller than (shorter than, the same height as) yours.
5. Suppose that each line represented 10 centimeters rather than one centimeter. How tall would that be? Measure that on the wall. If each line represented 50 centimeters, how tall would your fist be?
6. When you look down on your fist, what do you see? [lines]
7. Are the lines equally spaced? Explain. [No, sometimes they appear closer together and other times they are further apart.]
8. Find an area where the lines are closer together. What do you think it means when they are closer together? [It is a steep place on my hand.]
9. What do you think it means when they are further apart? [The slope is more gentle, not so steep.]
10. Pretend you had a lazy ant for a pet. Plan a route that would be easiest for the ant to climb to the top of your hand. Describe the route. Are the lines close together or far apart?
11. Why would topographical maps be of interest to hikers?
12. Suppose your hand represented a mountain. Where do you think erosion would occur? Explain. What effect would the erosion have on the contour lines?

Extensions

1. While students have the plastic wrap on their fists, take photographs looking down on their fists so they have a record of the contour lines.
2. Draw contour lines on various items such as a giant chocolate candy kiss that is still wrapped in foil.
3. Allow time for the students to switch roles, the one with the fist in plastic wrap and the one drawing the contour lines. Have students compare the lines of both their "topographical maps."

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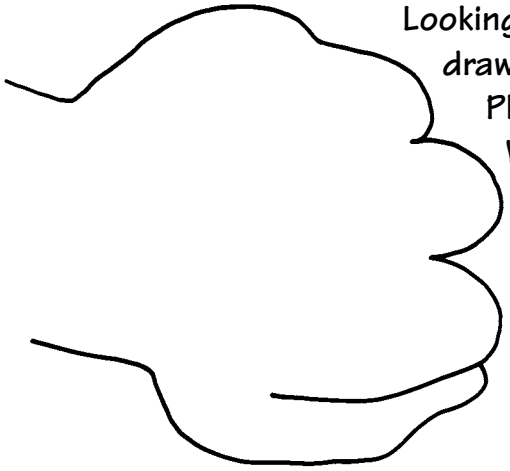
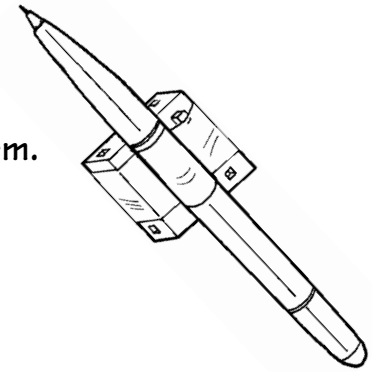
Handy Maps

Contour interval = 1 cm

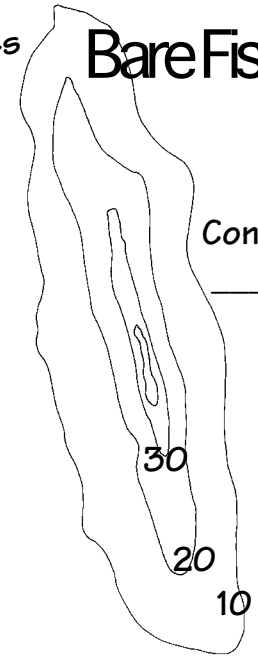


Looking down on your Handy Mountain, draw the contour lines as you see them. Place an X on the highest spot. What is the height of the highest contour line?

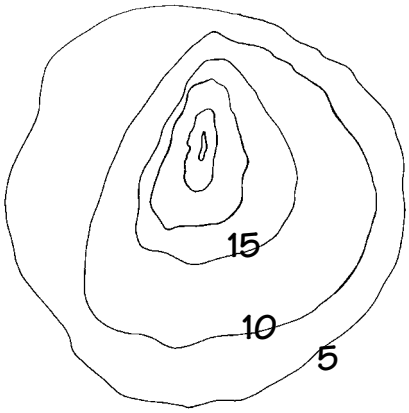


On the mountains below, finish recording the heights of the contour lines.

Bare Fist Summit

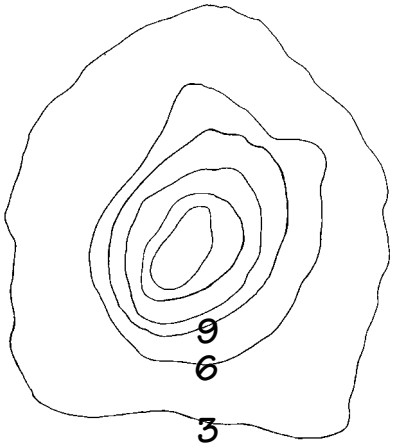


Contour interval = _____ m



Contour interval = _____ m

Paw-Paw Mountain

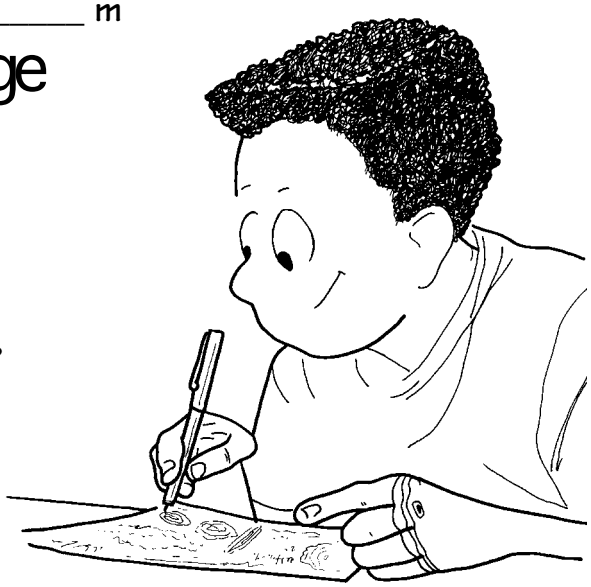


Contour interval = _____ m

Knuckle Ridge

Which mountain is the highest?

Does it have the greatest number of contour lines?
If not, how can it be higher than one with more lines?



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Mystery Mountain

Topic
Contour mapping

Key Questions
1. If you were on a backpacking trip, how could you actually *see* how high you are going to climb?
2. Which mountain matches this map?

Focus
Students will draw cross sections of a contour map, double the area of the map, and construct a three-dimensional replica.

Guiding Documents
National Geography Standard
- *Use cardboard, wood, clay, or other materials to make a model of a region that shows its physical characteristics*

Project 2061 Benchmarks
- *Measure and mix dry and liquid materials (in the kitchen, garage, or laboratory) in prescribed amounts, exercising reasonable safety.*
- *Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.*

NCTM Standards
- *Make and use measurements in problems and everyday situations*
- *Visualize and represent geometric figures with special attention to developing spatial sense*

Social Science
Geography

Math
Measurement
  volume
Ratios
Patterns
Spatial sense
Scaling

Integrated Processes
Observing
Making and reading maps
Classifying
Comparing and contrasting
Interpreting data
Applying

Materials
For each map:
  125 ml water (1/2 cup)
  125 ml salt (1/2 cup)
  250 ml flour (1 cup)
  16-cm square cardboard map base
  small resealable plastic bag

For the class:
  metric rulers
  dinner knives
  rolling pin
  tables or other flat surfaces
  straight pins
  transparency of the six maps

Background Information
Contour or topographical maps are used to show varying elevations. The National Forest Service, National Park Service, city planners, landscapers, land developers, and hikers use them.

Originally geographers mapped most of the United States using transits (surveyor's instruments for measuring horizontal angles) and levels, a time-consuming process. They marked permanent points at a known elevation, usually with a brass plate. These bench marks are used by surveyors and engineers to find the elevation of other objects. Many mountains and other geographical points were named by and for these geographers. Large area maps are now generally drawn using aerial photography and ground-checking.

A mountain is a part of the land that rises at least 610 m (2,000 ft.) above the surrounding area. One-fifth of the continents are covered by mountains. There are many in Asia, but few in Africa and Australia.

While it is the policy of AIMS to utilize the metric system, this activity uses foot measurements since this is the current common reference used for mountain heights in the United States.

Management
1. This activity is intended for groups of two to three. It is divided among three days. On *Day 1*, draw cross sections and enlarge *Map A*. On *Day 2*, form the flour/salt maps. If space is limited, consider having part of the class build their maps each day until all are done. It will take several days for the maps to dry. On *Day 3*, paint the maps.
2. Prior experience with transferring a drawing from a smaller grid to a larger grid is highly recommended.
3. Familiarize yourself with the procedure for marking cross sections (see *Procedure 6*).
4. The flour/salt recipe listed in *Materials* uses 2 parts

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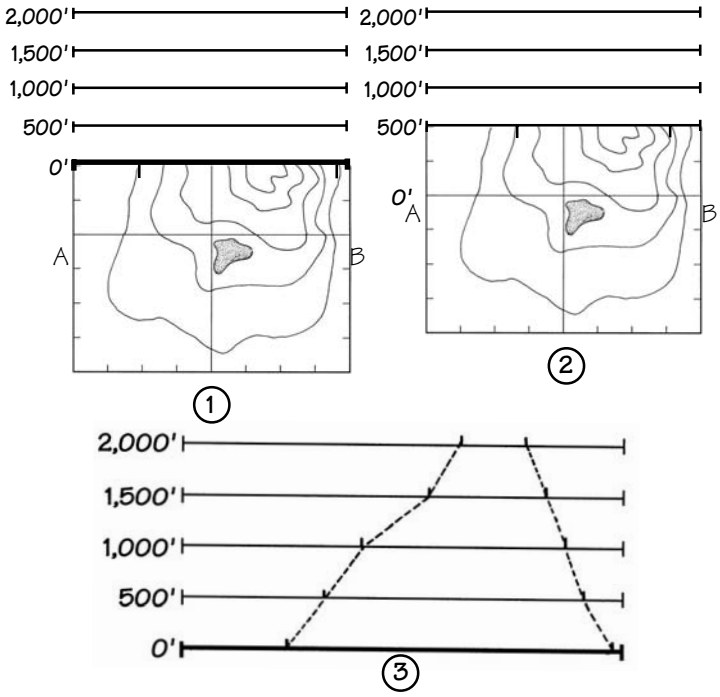
flour, 1 part salt, and 1 part water. Put the salt and flour into a plastic bag and add water until the dough is stiff enough to form a ball, but is not sticky. It is likely you will not need all of the water.

5. Cover flat tables with butcher paper and sprinkle with flour before rolling dough.

Procedure

Day 1

1. Ask the first *Key Question*. Give each group one of the contour maps, two copies of the *Map A* and *B* sheet, and the cardboard base.
2. Have each group glue their contour map in the space labeled *Map A*. It may be glued in either direction.
3. Instruct students to draw the grid lines, using the marks 1 cm apart on *Map A* and 2 cm apart on *Map B*. They should also draw the grid lines on the second copy of *Map B*, cut it out, and glue it on the cardboard base.
4. Direct students to enlarge *Map A* on *Map B* (first sheet) by duplicating the line patterns, square by square.
5. Have students record the scale for *Map B* by doubling *Map A's* scale.
6. Distribute the cross-section sheet and instruct students to draw the cross sections of both maps. Find the line labeled *AB* on *Map A*. If it goes through the highest contour of the mountain, use this line to mark each elevation as shown below. If it does not cross the highest elevation, use a parallel grid line that does. It is helpful to fold along the chosen line. On the bottom line of the cross section, mark the outermost contours. Then move the map up to the 500-foot line and mark the next contour. When all the marks have been made, connect them with lines. Complete *CD*, *EF*, and *GH* in the same way.

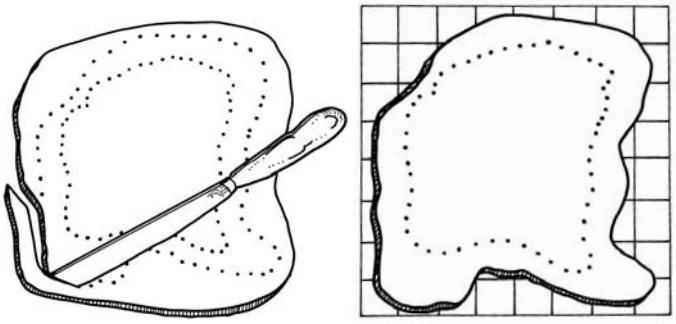


Mark the outermost contour at 0 feet (1), the second contour at 500 feet (2), etc. Then connect the marks(3).

7. Compare the cross sections of the larger and smaller maps. (Students should come to realize that distortions can be created by changing either the horizontal or vertical scale used for a cross section.)

Day 2

8. Have each student mix the dough in a resealable plastic bag, then roll or pat it to about 1/2 cm thickness. Instruct each one to put their *Map B* drawing over the dough and puncture it with a pin along the outer two contour lines. Remove the paper and, with a dinner knife, cut the dough along the pin holes of the outermost contour line. (The other pin-pricked line defines the placement for the next layer of dough.)



Marking and cutting a layer of dough. **Placing the layer on the grid.**

9. Direct each student to transfer and position the first dough layer on the cardboard base, matching the cross-section letters and grid lines with that of the pattern. Repeat the process for each successive layer, aligning that layer with the pin-pricked line on the preceeding layer. When the layers have been completed, pat the edges lightly to blend the mountain contours.
10. Let the maps dry.

Day 3

11. Together, study elevation maps, agree upon a color key, and paint the map. (Generally, greens and yellows are used for low elevations while browns, reds, and sometimes purple and white are used for the high elevations.)
12. Assemble all the relief maps in one place, pick one up at a time, and ask the second *Key Question*. Have students find the matching mystery mountain. A second option is to give all the maps and mountains letter and number codes. Individuals or small groups can take turns recording matching pairs on a piece of paper.
13. Continue with other *Discussion* questions.

Discussion

1. Why are the cross sections of *Map A* and *Map B* different? [When the horizontal distance, but not the vertical distance (elevation), increases, every-

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thing appears flatter or more spread out. (People can manipulate data by choosing a scale which dramatizes the point they want to make.)]

2. Which mountain matches this map? (Hold up one of the six maps.)
3. Find pairs of mountains that match.
4. Which mountain is a mesa (flat top and steep sides)?
5. If your mountain has a lake, what would be the most likely path of a river flowing from it?
6. When might you want to consult a contour or topographical map? [if you were building the transcontinental railroad or highways, going on an expedition, going on a backpacking trip, finding a lost person, planning a city, locating a home or business outside a flood plain or avalanche area, etc.]

Extensions

1. Double *Map B* and draw a cross section. Compare to the cross sections of *Maps A* and *B*.
2. Bring USGS topographical maps and/or hiking books which show cross sections of trails. One such book is *Sierra South* by Thomas Winnett, published by Wilderness Press (Berkeley, CA).
3. Make up your own map and follow the same procedure.
2. See the AIMS publication, *Through the Eyes of the Explorers,* for other activities dealing with topographical maps.

Curriculum Correlation

Art/Math/Writing

Design and mark a hiking trail to the top of your mountain. Determine the approximate length of the trail. Write about your hike. Would it be easy, moderate, or strenuous? What kind of vegetation and animal life would you see? Would you camp overnight? What would the weather be like? During what month would you go?

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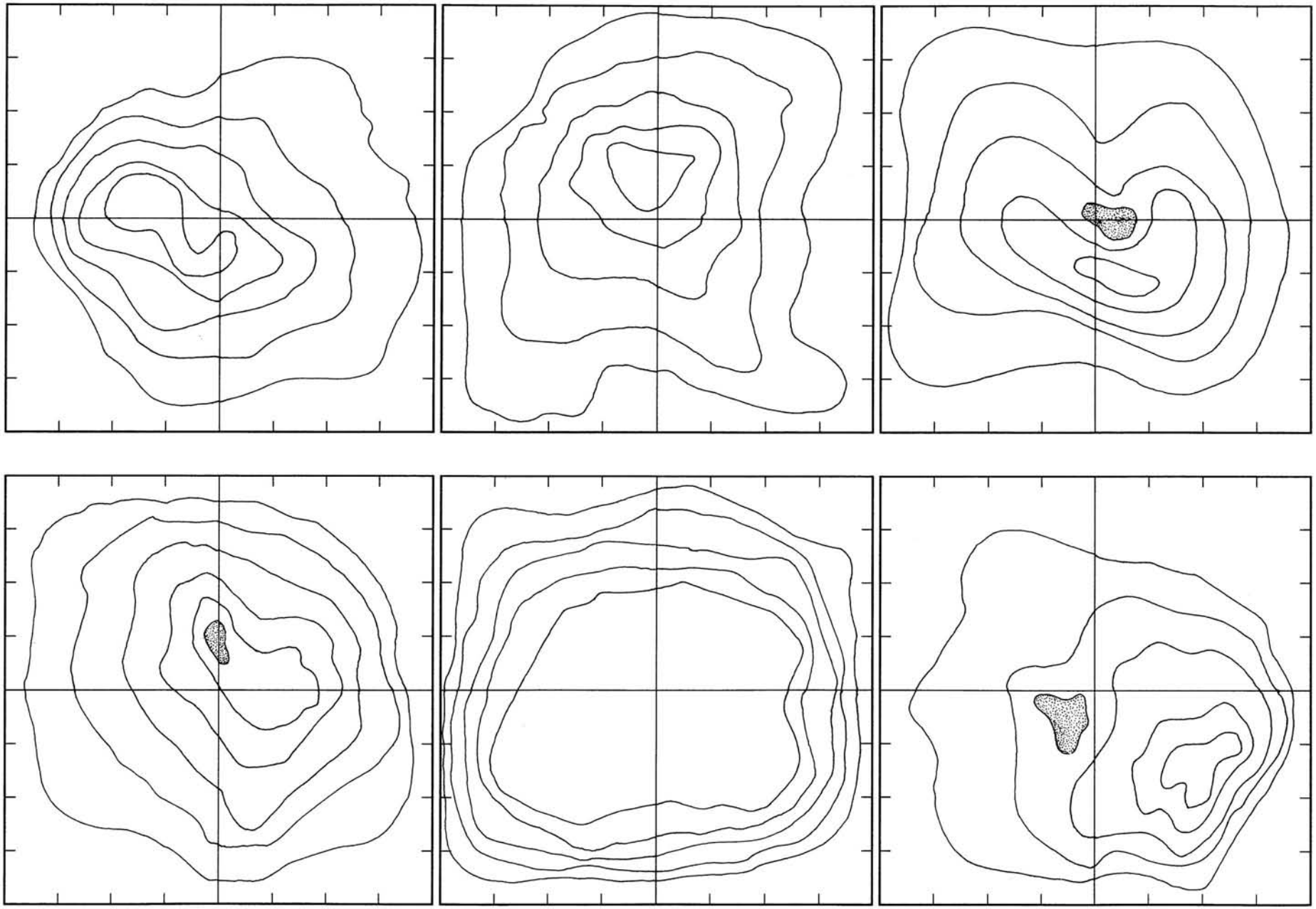
Mystery Mountain

Give one map to each group.



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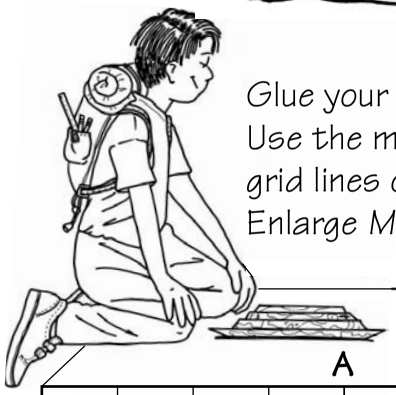
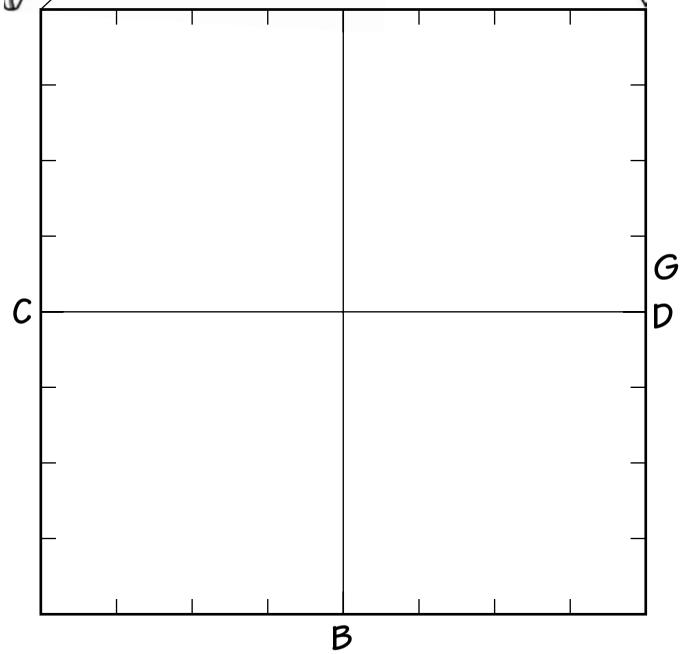
Mystery Mountain



Glue your map on *Map A*.
Use the marks to draw grid lines on both maps.
Enlarge *Map A* on *Map B*.



MAP A

Scale: 1 centimeter = 1 mile

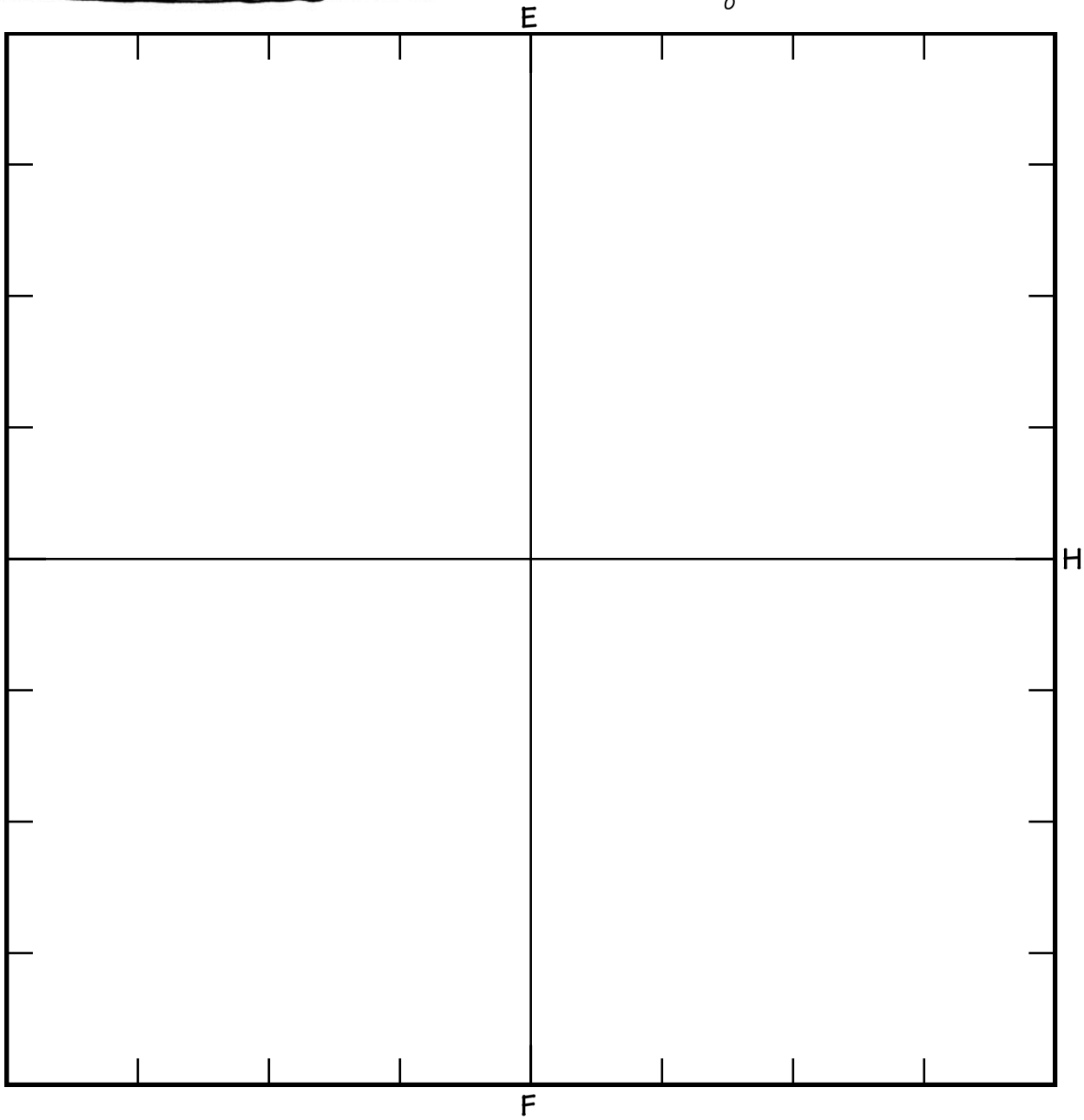
0 1 2 3 4

Contours: 500 feet

Lake

MAP B

0



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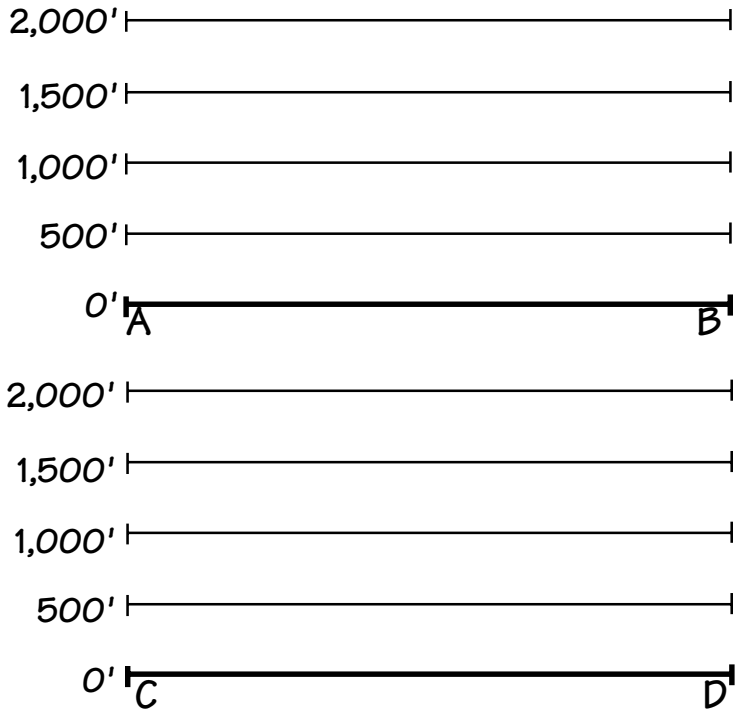
Mystery Mountain

MAP A
Cross Sections



MAP B
Cross Sections

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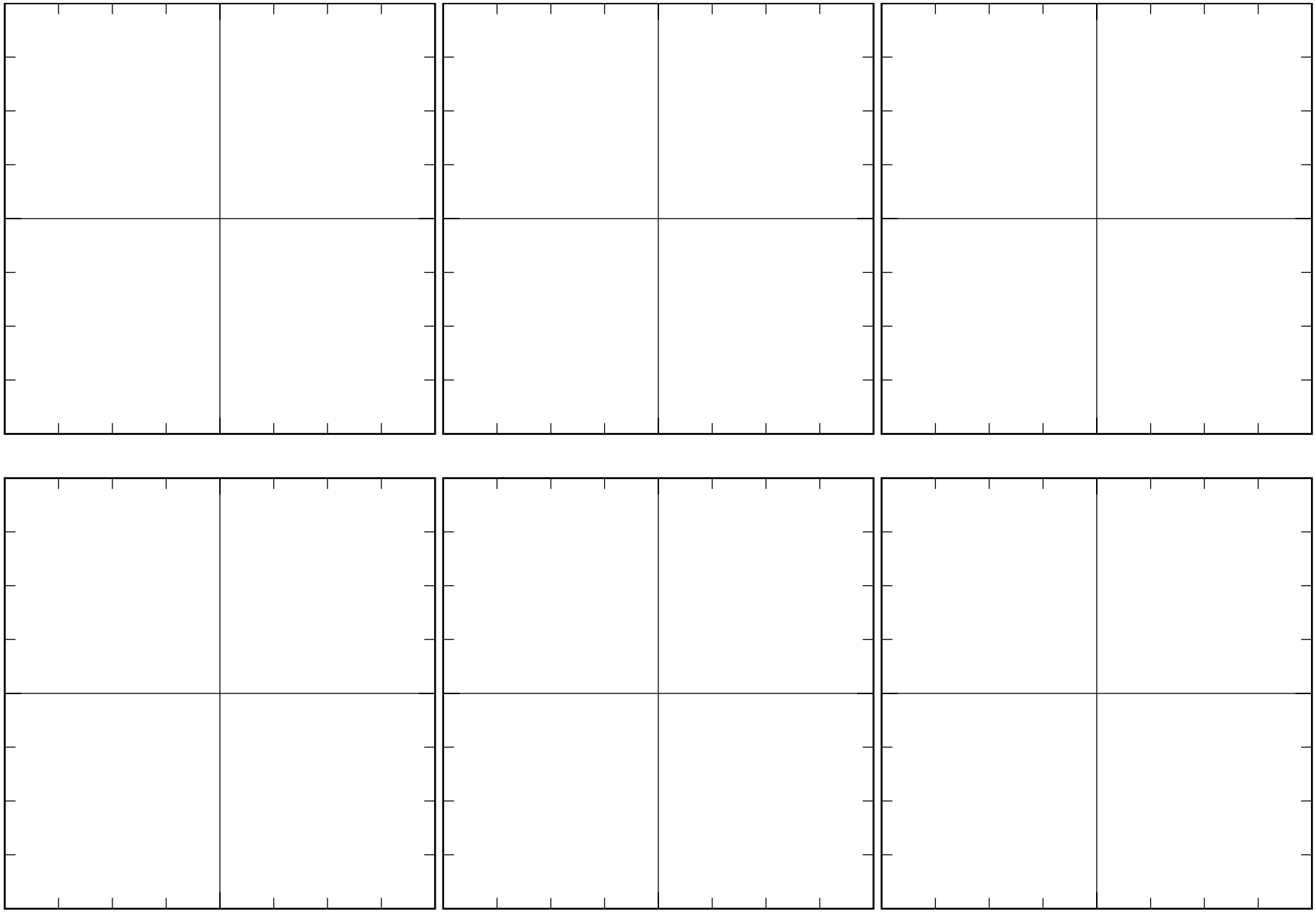
Mystery Mountain

Give one map to each group.